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RECENT DISCOVERIES IN HEREDITY AND THEIR BEARING ON ANIMAL BREEDING.*

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EVERY breeder of animals is familiar with the great complexity of hereditary processes. He knows that characters of the most varied sorts are inherited. These relate not only to general size and proportions, but also to the structure of individual parts; and not merely to structural, but to functional peculiarities as well. Thus, in certain races or strains of animals, we find inherited great fecundity, or early maturity, or ability to put on fat, or to produce abundant milk; in other cases, speed, keen scent, fierce or gentle disposition, and numberless other characteristics are plainly inherited. Very rarely are any two heritable traits *necessarily* associated. The cow with a good flow of milk may or may not be gentle; the keen-scented dog may or may not be speedy. Accordingly, we must conclude that different hereditary characters are inherited independently of one another, and are probably represented by different structural elements in the sexual element or germ. We know, further, that the laws of transmission of different characters are different, so that we can not estimate the force of heredity in the lump, but must fix our attention on one character at a time if we wish to analyze the complex processes in operation.

Francis Galton (1889) was the first to recognize that in the case of certain characters the result of inheritance is a *blend* of the conditions

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found in the two parents, while in other characters inheritance is *alternative* between the conditions found in the parents.

FIG. 1. A BROWN-COATED, LOP-EARED RABBIT.

FIG. 2. AN ALBINO, SHORT-EARED ANGORA RABBIT.

A good illustration of blending inheritance is found among rabbits which differ in size of ear. Lop-eared rabbits have ears two or three times as long and as wide as those of ordinary rabbits. (Compare Figs. 1 and 2.) A cross between lop-eared rabbits and ordinary ones

produces offspring with ears of intermediate size, which sometimes stand erect and sometimes lop. (See Fig. 3.) The ear-characters which were so distinct in the parents have in this case lost their identity in the offspring, and apparently can not be recovered again in their original condition, for the offspring transmit to their young the blended character, rather than the extreme conditions found in their respective parents.

It has been thought until quite recently that hereditary processes in general were of this sort and that any result other than a blend was exceptional. But recent investigations do not bear out this idea.

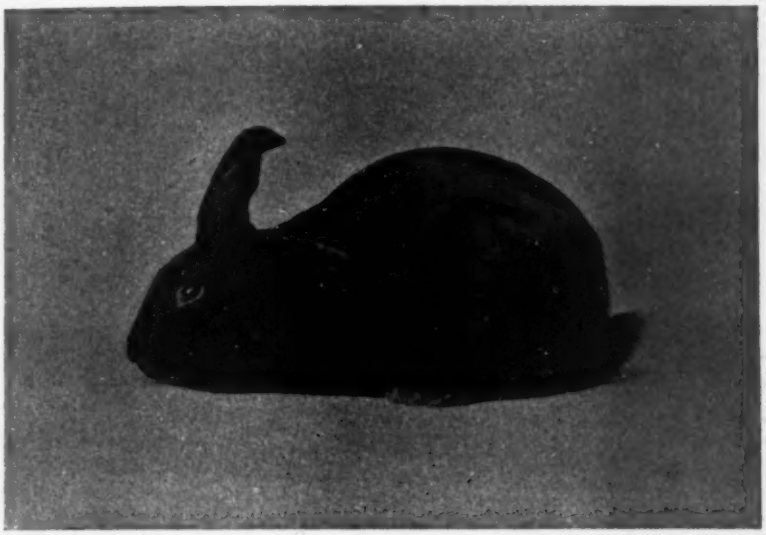


FIG. 3. A BLACK-COATED, HALF-LOP RABBIT, son of the two rabbits shown in Figs. 1 and 2, respectively.

Alternative inheritance is illustrated in a cross between the so-called Belgian hare and an albino rabbit. The Belgian hare is simply a gray-coated variety of the European rabbit, while albino rabbits are pink-eyed animals of the same species and have white hair; the Belgian is pigmented like the wild European rabbit, the albino is essentially unpigmented. A cross between the two produces offspring all of which have the pigmented or Belgian coat, none being albinos. Compare Fig. 3; in this case the parents were an albino and a brown pigmented animal, respectively. The young, nine in number, were all black pigmented, like the one shown in Fig. 3.

The effect of crossing a pigmented rabbit with an albino is similar to that produced when two pieces of glass, one transparent, the other opaque, are held up together. We see only the opaque one. Nevertheless, the two conditions have not blended; each retains its original dis-

tinctness, and the two can be separated again at will. So it is in the Belgian produced by cross-breeding with an albino. The albino character is there, though unseen, and will appear as a distinct entity when the cross-bred reproduces, for it will be represented in approximately half of the sex-cells formed by the cross-bred animal, the alternative or Belgian character being represented in the other half. It is as if the two pieces of glass, combined originally to illustrate the formation of a cross-bred animal, were separated again to illustrate the formation of the reproductive elements by the cross-bred. For every element formed having the opaque character, there will be another

FIG. 4. A GUINEA-PIG WITH LONG, ROUGH, ALBINO COAT.

having the transparent character, but there will be no elements of an intermediate nature.

This simple principle, that in alternative inheritance sex-cells of two sorts are formed by cross-bred individuals, constitutes one of the most important discoveries ever made in the study of heredity. The discovery was made about forty years ago by an Austrian monk, Gregor Mendel, who was engaged in the study of cross-bred garden peas. It, however, attracted little attention at the time and was soon forgotten. Meanwhile, a great body of workers was studying with great minuteness the material basis of heredity, the sexual elements. Their investigations disclosed in the cell a complete basis for just this kind of alternative inheritance and led up to the rediscovery of Mendel's law simultaneously by several different experimental breeders, foremost among whom was the Dutch botanist, de Vries.

Mendel found that in cross-breeding between alternative characters, one uniformly dominates in the offspring from its very nature, while the other disappears. Just as, when the two pieces of glass are held up together we see only the opaque one, the transparent one being invisible. Mendel called the character seen in the offspring *dominant*, the unseen one he called *recessive*. In rabbits, the gray pigmented or Belgian hare coat is dominant over the albino coat, the latter being recessive (unseen) in cross-bred animals. Similarly, in mice, guinea-pigs, and even in man, mating of an albino with a pure, pigmented individual produces only pigmented offspring. In guinea-pigs the rosetted or rough coat is dominant over smooth (normal) coat (see

FIG. 5. A GUINEA-PIG WITH SHORT, SMOOTH, PIGMENTED COAT.

Fig. 6); and short coat is dominant over long (or angora) coat (Fig. 8). In rabbits, also, the normal or short coat dominates over the angora coat (Fig. 3), and the same is probably true in cats and goats as well.

Among guinea-pigs there occurs a series of alternative pigment types which show Mendelian relations one to another. If we write them in this order, (1) *agouti* (*i. e.*, black ticked with yellow, the ancestral or wild type of coat), (2) *black*, (3) *yellow*, (4) *albino*, we may say that each is dominant over all which follow it, and recessive in relation to all which precede it. Thus agouti mated with black, yellow or albino gives only agouti offspring; black mated with yellow or albino gives either black or agouti, but never yellow or albino, while yellow dominates over the albino only. In man, a condition of

hypophylangia (two-jointed instead of three-jointed digits) is dominant over the normal condition. In mice, the peculiar waltzing habit of so-

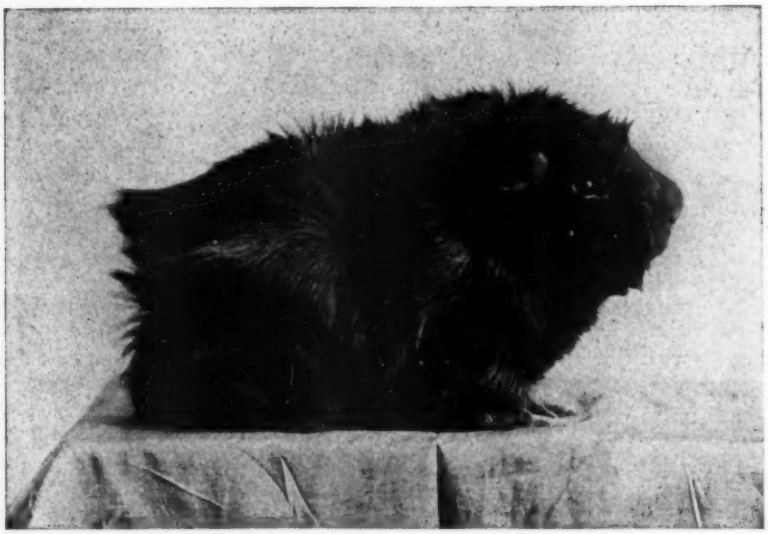


FIG. 6. A GUINEA-PIG WITH SHORT, PIGMENTED COAT. Its parents were the animal shown in Fig. 4 and one like that shown in Fig. 5.

FIG. 7. A GUINEA-PIG WITH LONG, SMOOTH, ALBINO COAT. These three characters are all recessive in nature.

called Japanese mice is a recessive character in heredity. In man, a peculiar dark-colored condition of the urine, known as alkaptonuria, is

inherited as a Mendelian recessive character. Many other illustrations might be given, but these will, perhaps, suffice to show that Mendelian

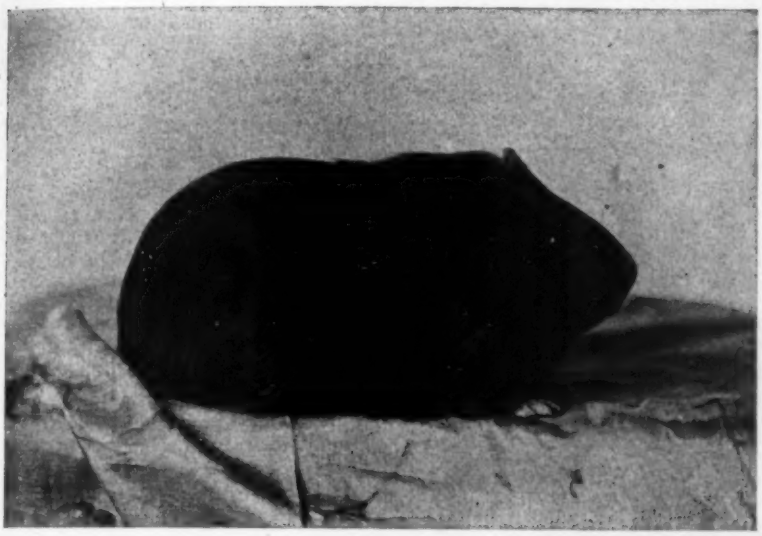


FIG. 8. A SHORT-HAIRED, SMOOTH, PIGMENTED GUINEA-PIG, illustrating the result of mating two animals like those shown in Figs. 5 and 7 respectively.

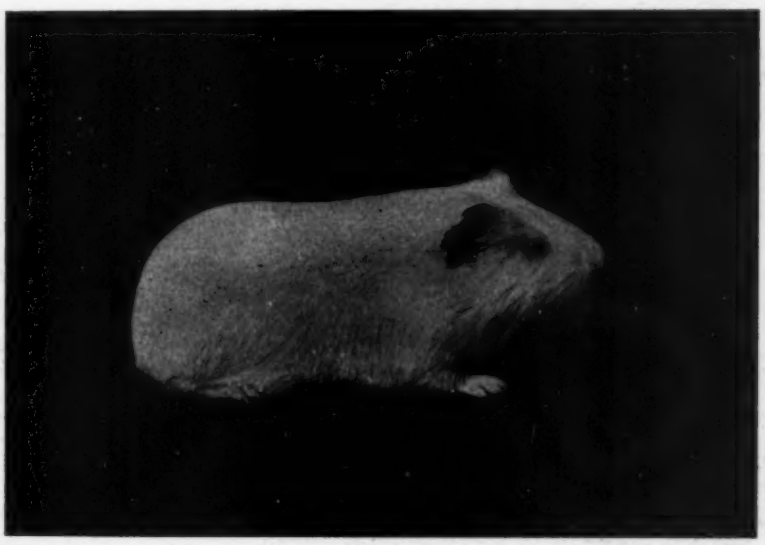
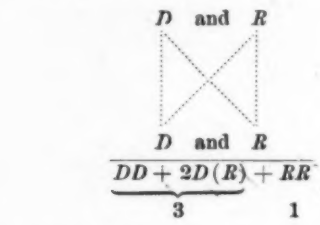


FIG. 9. A SHORT-HAIRED, SMOOTH, ALBINO GUINEA-PIG.

or alternative inheritance is neither a rare nor an exceptional phenomenon, and that it applies to the inheritance not only of characters purely structural, but also to those which are physiological.

From the facts that cross-bred animals form sexual elements (or gametes) of two sorts, and that the two sorts are equally numerous, it follows that among their offspring dominant and recessive individuals will occur in definite proportions. It has been found by experiment that when two cross-bred (or hybrid) dominant animals are mated together, the offspring consist of a mixture of dominant with recessive individuals in approximately the proportions, three dominant to one recessive. Further, when a hybrid dominant is mated with a recessive animal, half the offspring are hybrid dominants, half recessives. These proportions of necessity result, provided neither sort of gamete has greater affinity for one kind than for the other. For consider all the possible unions between two sets of gametes each *D* and *R* (the case in which two hybrid dominants are bred together):



They are 1 *DD*, 2 *DR* and 1 *RR*, or three unions involving the *D* character to one involving the *R* character only; hence three dominant individuals will be produced to one recessive. Further, one of the three dominants (*DD*) will be pure, while the other two are hybrid in character. Recessive individuals are, however, necessarily pure and breed true *inter se*. Thus, smooth-coated guinea-pigs produce only smooth-coated offspring, albinos only albino offspring, and long-haired ones only long-haired offspring, when mated to animals like themselves. The reason for this will be clear if we return to the illustration with the glass plates. Pairs of transparent plates can be separated only into transparent pieces, and these can be recombined only into transparent pairs.

With the dominant offspring of hybrids, however, the case is different. Only pure dominants (*DD*) will breed true when mated *inter se;* hybrid dominants (*DR*) will continue to give a mixed progeny. For pairs of opaque plates, when separated, can be recombined only into opaque pairs; but pairs composed each of an opaque and a transparent plate, when separated, may be recombined either into opaque pairs or into transparent pairs, the chance frequencies of the two sorts of combination being as three to one.

Accordingly, any pair of recessive individuals may form the beginning of a pure race of recessives, but in starting a pure race of dominants we must test each animal used, to make sure that it does not

contain, unseen, the recessive character. Otherwise we may keep getting mixed lots of offspring. The simplest and surest way of making such a test is to mate the dominant animal with a recessive. For in that case, if the dominant is pure, all the offspring will be dominants; but if the dominant parent is a hybrid, half the offspring will be recessives, half dominants. When the purity of two dominant animals of opposite sex has once been established by breeding-test, we may use them as the starting point of a race of dominants which we may be sure will breed true.

We must not, however, fall into the error of supposing that any pair of dominants which produces only dominant offspring is, therefore, pure. For progeny of this sort will be obtained if only *one* of the parents is pure, the other being hybrid. In starting a race of dominants which will breed true we must test each animal individually, by mating it, preferably with a recessive, or else with a dominant known to be hybrid in character. A test of the former sort should, as stated, give 50 per cent. of recessive individuals if the dominant is impure; a test of the latter sort should give 25 per cent. of recessives, if the dominant is impure. Either sort of test should give only dominant offspring if the dominant tested is pure.

The statement has already been made that many characters are independent of one another in heredity; I hope now to demonstrate the correctness of this idea in cases of alternative inheritance, even when the independent characters relate to the same bodily parts. For this purpose the coat-characters of guinea-pigs and rabbits are well adapted, since they are exterior structures easily studied in the living animal. I hope to show first that pigmentation of the hair is inherited quite independently of its length, and secondly that hair-arrangement (in smooth or rough coat) is inherited quite independently of both pigmentation and length of hair.

When an ordinary short-haired guinea-pig (Fig. 5) is mated with a long-haired albino guinea-pig (Fig. 7), all the young produced are short-haired and pigmented, these being the dominant characters. (See Fig. 8.) Now if the cross-bred young are bred together, offspring of four different sorts are produced. Two of the four sorts are identical with the grandparents in character; they are short-haired pigmented animals (Fig. 5) and long-haired albinos (Fig. 7), respectively. But the other two sorts represent new combinations of characters; they are short-haired albinos (Fig. 9), and long-haired pigmented animals (Fig. 10). Further, these four sorts of individuals occur on the average in definite numerical proportions, viz:

9 short-haired pigmented animals,
3 short-haired albino animals,
3 long-haired pigmented animals, and
1 long-haired albino.

Considering pigmentation and hair-length separately, we see, first, that there are 12 pigmented animals to 4 albinos, or 3 to 1, as expected; and, secondly, that there are 12 short-haired to 4 long-haired animals, again 3 dominants to 1 recessive. But if we consider the relation of each pair of characters to the other, we find absolutely no correlation between them. Albinism may or may not be associated with long hair, and pigmented coat may or may not be associated with short coat in the offspring, though they were so associated in the grandparents. As a matter of fact, when the animals are tested one by one, to determine the presence of recessive characters, we find that albinism, visibly present in 4 out of 16 offspring, is present recessive in 4 others, and that in half

FIG. 10. A LONG-HAIRED, SMOOTH, PIGMENTED, GUINEA-PIG.

of these cases it is associated with short coat, while in the other half it is associated with long coat.

In another experiment which I have performed with guinea-pigs, a cross was made involving three pairs of alternative coat-characters, length, pigmentation and roughness of coat. A long-haired rough albino (Fig. 4) was mated with short-haired smooth pigmented animals (Fig. 5). The young were all short-haired, rough and pigmented (Fig. 6). The coat-characters seen in these offspring are the three dominant characters, two of which were received from one parent, one from the other; the three alternative recessive characters are present but unseen.

When the young were bred together, they produced offspring of eight different sorts, including all possible combinations of the three pairs of alternative characters.

One large class was like the parents, short-haired, rough and pigmented. Two other classes were like the grand-parents, viz, short-haired smooth pigmented, and long-haired rough albino. In addition, there were five other new classes not represented among the parents or grandparents. These were: short-haired rough albino (Fig. 11), short-haired smooth albino (Fig. 9), long-haired smooth albino (Fig. 7), long-haired smooth pigmented (Fig. 10), and long-haired rough pigmented (Fig. 12).

The eight classes of young produced in this experiment are not all equally numerous. The largest class is that which contains the three dominant characters (Fig. 6), the smallest that which contains the

FIG. 11. A SHORT-HAIRED, ROUGH, ALBINO GUINEA-PIG.

three recessive characters (Fig. 7). Theoretically, they should number 27 individuals and 1 individual, respectively, in a total of 64 young. These proportions are roughly approximated in the observed result.

This experiment illustrates two important principles in heredity: First, if as regards the hair alone there exists such a variety of characters separately heritable, how great must be the number of such characters in the body as a whole, and how remote the probability that any animal will in all characters resemble any individual ancestor, provided that in a considerable number of heritable characters a choice is offered between alternative conditions. Secondly, the experiment shows how a variety of new organic forms may quickly be produced by cross-breeding, leading to the combination in one race of characters previously found separately in different races. Thus, in

guinea-pigs, one can obtain within two generations any desired combination of the three pairs of alternative coat-characters, if one pro-

FIG. 12. A LONG-HAIRED, ROUGH, PIGMENTED GUINEA-PIG.

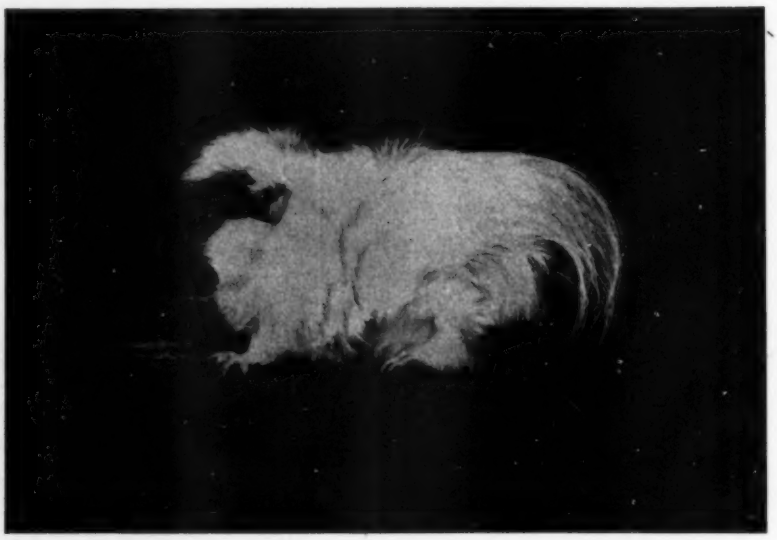


FIG. 13. AN IMPERFECTLY LONG-HAIRED GUINEA-PIG. Compare Figs. 4, 7 and 12.

duces a sufficiently large number of individuals; but to obtain the desired combination in individuals which will *breed true* is not so simple a matter. If the desired combination consists wholly of reces-

sive characters, any pair of individuals manifesting that combination will breed true. But if the desired combination contains one or more dominant characters, then each animal selected must be tested for the presence of undesirable recessives before one can be sure that the new race will breed true. In practise it is found best by the breeder not to work with too many characters at a time, but to eliminate the undesirable recessives one by one. Otherwise the search for the one individual in a large number which will breed true may prove a long and tedious process. If we deal with one character at a time, the chances are that one in four of the second generation of animals reared will meet our ideal; if we deal with two characters at a time, the chances are one in sixteen; while if we deal with three characters at a time the chances are only one in sixty-four; and so on, with the chances of success diminishing in a geometrical series.

From what has thus far been said it would appear that in alternative inheritance characters behave as units, and, more than that, as *wholly independent* units, so that to forecast the outcome of matings is merely a matter of mathematics. While this is in a measure true, it is, fortunately or unfortunately, not the *whole* truth. In alternative inheritance characters do behave as units independent of one another, but the union of dominant character with recessive in a cross-bred animal is not so simple a process as putting together two pieces of glass, nor is their segregation at the formation of gametes so complete in many cases as the separation of the two glass plates. The union of maternal and paternal substance in the germ-cells of the cross-bred animal is evidently a fairly intimate one, and the segregation which they undergo when the sexual elements are formed is more like cutting apart two kinds of differently colored wax fused in adjacent layers of a common lump. Work carefully as we will, traces of one layer are almost certain to be included in the other, so that while the two strata retain their identity, each is slightly modified by their previous union in a common lump.

Thus, when we cross short-haired with long-haired guinea-pigs, we get among the second-generation offspring a certain number of long-haired animals with hair *less* long than that of the long-haired grandparent, or with long hair on *part* of the body only (Fig. 13). Further, certain of the short-haired animals have hair a little longer and a little softer than that of the short-haired grandparent. Again, rough-coated guinea-pigs produced by cross-breds often have coats less fully rough than that of their rough ancestor, lacking certain of the typical rosettes (Fig. 14). Finally, when an albino is crossed with a fully pigmented animal, the result may be not a wholly pigmented animal, but one spotted with white. While such a cross-bred animal forms a full quota (one-half) of albino gametes, the pigment-bearing gametes formed by it frequently bear this spotted or modified pigmented condition.

Cross-breeding, accordingly, is a two-edged sword which must be handled carefully. It can be used by the breeder to combine in one race characters found separately in different races, but care must be exercised if it is desired to keep those characters unmodified. If modification of characters is desired at the same time as new combinations, then cross-breeding becomes doubly advantageous, for it is a means of inducing variability in characters, as, for example, in the intensity of pigmentation and in the length of hair, quite apart from the formation of new groupings of characters. Sometimes it causes a complex character to break up into simpler units, as the agouti coat of the wild guinea-pig into segregated black and yellow, or total pigmentation into

FIG. 14. AN IMPERFECTLY ROUGH-COATED GUINEA-PIG. Compare Fig. 6.

a definite series of pigmented spots. In other cases it operates by bringing into activity characters which have previously been latent in one or other of the parental forms. Compare Fig. 3 with Figs. 1 and 2. Black pigmentation was latent in the albino parent (Fig. 2) and was brought into full activity by a cross with a brown-pigmented animal.

Now, what bearing, we may ask, have these theoretical matters on the practical work of the breeder? They show (1) that a race of animals is for practical purposes a group of characters separately heritable, and (2) that the breeder who desires in any way to modify a character found in this group, or to add a new character to the group, should first consider carefully how the character in question is inherited.

If the character is alternative in heredity to some other character,

cross-breeding between the two, followed by selection for pure individuals, will within two generations give the desired combination of characters in individuals which will breed true. This process of selection is simplest when the characters to be combined are recessive in nature, but individual breeding-tests become necessary when dominant characters are included in the combination desired.

If a character gives blending inheritance, it must be treated in a different way. Suppose, for example, that we desire to combine lop-ears in rabbits with albinism, but that our lop-eared stock consists wholly of pigmented animals. How shall we proceed? First, mate a pigmented lop- (Fig. 1) with a short-eared albino (Fig. 2). The offspring will be pigmented half-lops (Fig. 3). If two of these be bred together their young will all be half-lops, and about one in four of them will be albinos. Now these albino half-lops may be mated with pure pigmented lops. The young will again all be pigmented, but will this time be *three-quarter* lops, and by breeding these together albino three-quarter lops may be obtained in the next generation. By continuing this process of back-crossing with the lop-eared stock, and selecting the albino offspring obtained, the lop-eared character may be steadily improved in the albinos until it is practically as good as in the original lop-eared stock. The rate of improvement possible can be readily calculated. The albino young will be:

After 2 generations, one half lops,
After 4 generations, three fourths lops,
After 6 generations, seven eighths lops,
After 8 generations, fifteen sixteenths lops,
After 10 generations, thirty-one thirty-seconds lops, etc.

This will be the result on the hypothesis that no secondary variation occurs in the lop-eared character. If, however, variation is induced by the cross-breeding, then it is possible that the desired end may be reached sooner, or that an even better lop may be obtained in the albino cross-breds, than that of the original pigmented stock.

Latent characters are an important element in practical breeding. Sometimes they greatly aid the breeder's work; sometimes they impede it. If a stock contains undesirable latent characters which are brought into activity by cross-breeding, these latent characters will have to be eliminated, or a new stock tried.

Since cross-breeding is likely to modify characters even when these conform to the laws of alternative inheritance, and is certain to modify them when they give blended inheritance, it should be practised with extreme caution, and only by the breeder who has a definite end in view and a fairly clear idea of how he is going to attain it.

The purity of standard breeds should be carefully guarded, and

much attention should be given to pedigrees; for even when individual excellence is not apparent, it may be present in a recessive or else in a latent state, which suitable matings will bring into full realization, provided the ancestors were superior animals.

At the same time the breeder should be on the lookout for individual peculiarities of merit. And he should not be discouraged if these are not transmitted to the immediate offspring. Ordinarily a desirable character which disappears from the children, but reappears among the grandchildren, can at once be made a racial character, for it is recessive in heredity.

Inbreeding is not invariably an evil. It is often necessary to cause the reappearance of a vanished recessive character, and is indispensable in the formation of races which will breed true. Two or three generations of close inbreeding usually suffice to realize the practical benefits of the process, if intelligently carried on. The inbreeding should then be discontinued as soon as the desired end has been attained. Otherwise, loss of vigor or infertility may result.

PRESENT MONETARY PROBLEMS.*

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I.

THE development of thinking about money is the most interesting portion of the history of political economy. The first dawn of economic principles came with the discussion of monetary phenomena, and monetary science has not only always had a peculiar practical interest of its own, leading to its constant appearance in political campaigns in all countries, but it has also had an organic life persisting in its full vigor to the present day. In the United States, the monetary question is not at this very moment—as it has been—the football of the political parties; but there has been very recently an active upheaval in scientific discussion which is healthy and worthy of attention. In Europe, while the active discussions of bimetallism have simmered down to relative quiet, yet the interest in the fundamental monetary questions among scholars is burning with a clear flame. These present monetary problems are not only enlisting the interest of economic thinkers and reach the very center of systematic exposition, but they also happen to be those which have to do with the truth or error of convictions which are widespread among great masses of our countrymen.

It is passing strange that the vast literature of money has not been marked by a burning zeal for the statement of an organic body of principles. Discussions of money have usually been started in some local, or practical, problem; and interest has centered largely in the acquisition of historical data, without any considerable success in the formulation of the principles explaining such data. Once the problem of special interest to the public had been settled for good or for ill, the real scientific interest seemed to wane. To-day, in my judgment, the case is entirely different. The attention now being given by scholars in both Europe and America to the vital questions of monetary doctrine is nearly as intense as that given to questions of wages and interest.

II. *Functions of Money.*

Since the time of Ricardo there has been a magnificent confidence that the theory of money has been so well settled that there was little

* Read at the International Congress of Arts and Science, at the Universal Exposition, St. Louis, in September, 1904.

more to be said on the subject. The economic dogma of money, at least, was supposed to be fairly complete. And yet—in my judgment—the systematic treatment of the principles of money has remained undeveloped almost to the present day. There is scarcely any part of the field which can be regarded as thoroughly disposed of. Indeed, the very definition of money itself is to-day under the most critical examination; and with the definition goes the question as to the functions performed by money. On these points—like investigators in other sciences—we must frankly admit our lack of agreement.

First of all, it should be emphasized that the dispute about the definition and functions of money is not merely a question of words; it relates, in truth, to fundamental problems of great practical import. Every day the statesman and man of affairs are confronted by difficulties connected with the primary effect of 'money' on prices in general; but it is at once patent that the relation of the value, or quantity, of 'money' to prices can not be disposed of until we have determined what we mean by 'money.' As at present used, 'money' has no scientific precision; it is often carelessly employed in many different senses by one and the same author.

Evidently, before a rational definition of money can be found, some agreement based upon an analysis and description of the functions actually performed by money must be reached. If several dissimilar services are rendered by monetary instruments; if each of these services is associated by usage with 'money'; and if it happens that different things are employed in these different services—then, while authors may agree as to many of the functions of money, it may easily happen that they may still disagree as to which shall be regarded as essential to the definition of money. Money may have different meanings according as it is made to include, or exclude, some or any unquestioned services associated by usage with money. In such ways, an important difference might arise between that which is money in an economic, or true sense, and that which is money in a legal sense. In fact, the economic relations of money ought to be scientifically ascertained before legal functions should be assigned to it. If, for instance, the state should apply the quality of legal tender loosely to some instrument which does not completely fulfil all the functions of money, then that money is not made thereby in the economic sense true money. It thus often happens that incomplete forms of money exist, which give the public much difficulty to classify and define. The expressions 'substitutes for money,' or 'surrogates,' or 'representative money,' have arisen which depend for exactness upon the primary meaning assigned to the money on which they depend. The very functions of money need careful limitation.

Among writers as late as John Stuart Mill, there is practically no separation of these functions. The term money was applied indifferently to an instrument which served only as a medium of exchange, or only as a standard, as the case might be. Obviously, it would not be possible here to summarize all the different ways in which the functions of money have been viewed: they vary with each writer. In the main, there is a discussion upon the merits of the following separate functions:

1. A medium of exchange.
2. A standard, or measure of value.
3. A standard of deferred payments.
4. A legal means of payment.
5. A store of value.
6. A means for transferring value or capital.

The most recent German writer, the distinguished scholar, Helfferich, in an epoch-making treatise,* holds that there are only two primary functions of money, neither being secondary to the other: (1) Medium of exchange, (2) means of payment. He does not regard the standard function as essential to the conception of money, believing that any such service as may be included under a measure of value has been derived from the two primary functions given above. With several other writers, he finds that the medium of exchange was the thing which first developed, and then came into general use as a standard, or measure of value. He practically defines money as everything serving to facilitate exchange between economic factors. Thus, Helfferich would hold that the state, by giving legal tender power to things worthless in themselves, such as irredeemable paper, created a means of payment for debts, and therefore he would include even such instruments as these under money, because they fall under one of his primary divisions.

Whatever conclusions may be reached in regard to the functions of money, their application to the system of any one country would raise difficult questions as to the classification of money. If one of the necessary functions is lacking to any one form of money, is it, or is it not, true money? For instance, in the United States, no one would hesitate to say that gold coin is true money, and yet it is very little used as an actual medium of exchange. Therefore, we may easily call that true money which does not serve principally as a medium of exchange. Also, silver dollars, and French five-franc pieces, in the so-called 'limping gold standard,' could not be called true money in all senses, because their value is dependent on a primary form of money. Like national bank-notes and greenbacks, they are only 'surrogates,' they are, perhaps, legal, but not economic, money in the fullest sense.

* 'Das Geld,' von Karl Helfferich, Leipzig, 1903, 8vo, pp. x + 590.

One may well doubt if the function of a means of payment can be distinguished from that of a medium of exchange. At least, most writers seem to agree that the medium-of-exchange function is essential to money; but if the standard function be neglected, could we possibly define that which acts only as a medium of exchange as true money? Of course not. Deposit-currency (*i. e.*, bank checks) certainly acts as a medium of exchange, and as a means of payment; but we should, in all common sense, be obliged to place such currency in a very different class from gold coin.

Therefore, every one must agree that the critical discussion of the meaning and functions of money is fundamental to scientific progress, and to all serious treatment of the main problems of money, such as the theory of prices.

III. *Credit.*

In regard to another unsettled problem of money, credit, it is to be said, not only that it has been very much misunderstood, but that it has been given very little real study. There is to-day no commonly accepted definition of credit: the element of futurity in a credit-transaction is generally admitted, but 'confidence' is by some regarded as the essential element; and yet 'confidence' can play its rôle only because futurity exists in the credit operation.

Nor is there any received opinion as to the real nature and functions of credit. We seem, in the whole field of credit, to be on the frontier of knowledge. In any true sense, the economic end of society is the possession and use of goods which satisfy wants. Credit has been devised as one of many means to aid in accomplishing this end. In its fundamental relations it has to do with goods and their increase. To some, however, it is related only to money. The truth of this concept, to my mind, depends upon the nature of money. If it be only a means to an end, and if it does not alter the elemental principles of value, but aids and cheapens the exchange of goods, then it is easy to understand that a borrower in reality obtains the use of goods, as the purpose of a loan, and that money and credit are but the instruments devised by society for effectually carrying out that purpose. Hence the credit operation, as regards extension or contraction, is primarily based on transactions in goods; its relation to money is a secondary, and incidental, connection. Credit being a transfer of goods involving the return of an equivalent in the future, forms of credit appear only as a consequence of transactions in goods. More transactions, not more money, cause an increase of forms of credit; and, by an interesting process of evolution, forms of credit—especially the deposit-currency of banks—act as a medium of exchange, obviating recourse to money. The belief, however, that credit depends on money,

and not on goods, is widespread, and much discussion is probably before us on this point.

The relation of credit to the theory of prices is not so clear: some think that all the money, plus all the credit (whatever that may be), act primarily to fix the level of prices; but any sane person will see at a glance that the forms of credit, such as bills, drafts, etc., arising from the movement of the wheat crop, have no effect on the price of that crop—the price having been made antecedent to the creation of the forms of credit which came into existence only because of the actual sales of wheat. Does a farmer wait until he sees how many wheat bills are drawn before fixing the price of his wheat? Evidently not; and the popular conception needs thorough criticism.*

When men speak of 'our expansion of credit,' they have a very vague and general idea in their minds. The definite and distinct forces at work are covered with darkness; and, when a revulsion of trade comes, the results are accepted as coming from some undefined and mysterious force which can only be felt, but not explained. It remains the duty of the economic thinker to outline with scientific exactness the forces uniting in the upward wave of over-trading, and to state with equal definiteness the causes of the receding movement. Principles must be sought for which will explain the differing actualities of each special crisis.

IV. *Theory of Prices.*

Only after the honest student has come to a satisfactory conclusion in regard to the nature of money and credit is he in a position to discuss with profit the pivotal problem of this field—the theory of prices. Perhaps I may be criticized for treating here the present monetary problems from too theoretical a point of view; and it may be urged that I should have presented the practical problems confronting each leading nation, and discussed their relations to the several monetary systems actually in use. But I must respectfully insist that the moment any practical problem in any existing monetary system is taken up, one is instantly faced by the difficulty of agreement upon the terms in use, and in fact upon the simplest monetary principles involved in the examination of each case. Every practical reformer in the field of money is in fact using some theory of prices, true or false, in all the premises laid down in his propositions. One might as well go into practical engineering without a knowledge of thermodynamics as to discuss practical monetary schemes without first settling basic monetary principles. But, unfortunately, the thinking, even among so-called economists, is to-day unsettled on so pivotal a ques-

* For a full discussion of credit, see my 'Principles of Money,' Chap. IV. (1903).

tion as the theory of prices. Practical monetary legislation, in more than one country, would be radically modified, accordingly as the so-called 'quantity-theory' of money is accepted or not. In my humble opinion, that theory is indefensible and erroneous; and yet our great politicians in the United States, in their fencing on the monetary problem, have decided that the question of the gold standard has been definitively settled, because of the large recent production of gold. The partisans of gold have thus accepted the principle on which the demands for an extension of the circulation of silver and greenbacks have been based in the past; and the position is absolutely untenable.

The issues in this crucial problem are unmistakable; and they must be threshed out to a conclusion before any practical applications can be attempted. These issues may be briefly stated in the following heads:

1. Is the price of goods the quantity of some standard commodity for which they will exchange, or is it the relation between goods and a variety of several media of exchange?

2. If true money is a commodity, like gold, then what determines the exchange value between goods and that commodity? Is the problem in any way different from that of obtaining the exchange value of any two commodities?

3. What is the actual process of evaluation between goods and gold?

4. If demand and supply regulate the value of money (cost of production apart), what is the exact meaning of demand for money, and of supply of money?

5. Is the demand for a money-metal only the monetary demand? Is the demand for a commodity *as money* something *sui generis?*

6. In the theory of prices, what is meant by 'money'? Is it only gold, or gold together with everything, such as deposit-currency, which acts as a medium of exchange? In short, what constitutes the supply of money?

7. If prices are influenced by 'purchasing power,' is that synonymous with the sum of the existing media of exchange, multiplied by their rapidity of circulation? Or, is purchasing power in its ultimate analysis synonymous with the offer of saleable goods?

8. Have the expenses of production, or progress in the arts, no influence on the general level of prices?

9. What is the effect of credit on general prices?

10. How do fluctuations in bank reserves actually affect general prices? Does the rate of interest, being paid for capital and not for money, have an effect on prices through its effect on loans?

11. By what economic process would a great new supply of gold influence general prices? Only by being directly offered for goods as a medium of exchange?

12. Does the Ricardian reasoning in favor of the quantity theory of prices hold in monetary systems where free coinage of the standard money exists, and where other devices are used as media of exchange? If mints are open, how can the coin differ in value from the bullion of which it is made?

It is safe to say that the thorough discussion of these points, and a satisfactory disposal of them, will aid in the solution of the central monetary problem, not only of the past, but of the present time. It is one which can not be blinked. It arises at every step in popular monetary discussions, and the economists have not given it necessary attention. On the settlement of the theory of prices, of the value of money, a host of minor questions, which have caused endless and fruitless differences of opinion, will disappear The solution of this matter of theory is of the greatest practical import; it is as important to practical monetary action as a theory of heat is to mechanics. Therefore let us not be deterred from a struggle with a fundamental matter of theory by any slighting and cheap sarcasm about the futility of theoretical and abstract discussions. As well scoff at the mathematics which lies behind physics and astronomy as theoretical.

Nor will it be wise to minimize the differences between the old and new points of view in the theory of prices. It may be said that the quantity of money would have an influence on general prices in any theory. True; but that does not touch the crucial point at issue. The quantity theorists make the process of evaluation between goods and 'money' dependent on the actual offer of the medium of exchange and goods for each other; an increase of transactions in goods is an increased demand for money, resulting, unless the quantity of money is increased, in falling prices. It is needless to say that the facts do not agree with these statements. An inductive economist, who would be unwilling to state any principle which had not been the outcome of a study of concrete data, could never, under any possible circumstances, have arrived at the quantity theory of money. In no case coming under my observation has there ever been any correspondence between the movement of general prices and the known facts as to the quantity of circulation, or the money-work to be done. If I am wrong, it lies in the power of induction to disprove my statement by the facts. In truth, the quantity-theory was the product of the metaphysicians, and not of the men of affairs; and it never has been in accord with the data of inductive study, so far as I know.

It is true that a great increase in the supply of gold would lower its value, other things remaining the same; but the effect on general prices would be a simple one, such as would be produced by any cheapening of the standard, like a change to a depreciated paper standard. But this change in the value of the standard is a radically

different economic process from that by which prices are said to be influenced only by changes in the quantity of the media of exchange actually offered for goods. One or the other must be wrong.

V. *Prices and the International Movement of Metallic Money.*

The settlement of the theory of prices, or the principles determining the value of money (suitably defined) has an importance reaching out into the field of the international movements of specie. We can not properly formulate the methods by which the shifting of specie and goods act upon each other in international trade without having previously reached a definite conclusion upon the theory of prices. Thus the examination of and agreement upon the theory of prices will largely determine the statements made concerning the relation between the shipments of specie and the level of prices within a country.

With the Ricardian formula, derived from the experience of England in the early part of the last century, writers have attempted to solve this problem by using the quantity of money in a country as the force regulating the general level of prices; if gold is exported, prices must fall; if gold is imported, prices must rise. In brief, the originating cause of a change in the general level of prices, so far as international trade is concerned, is the shipment of specie. The movement of goods is a consequence of the change of prices brought about by the addition or subtraction of specie. That is, the quantity-theory has been relied upon to solve this highly important and practical problem of money.

The original statement of Ricardo has, of course, been added to and emended; but, in the main, it is intended to show that any one country obtains a part of the world's circulation of specie in the proportion that its trade bears to that of other countries. This quota of gold, for instance, is retained in a country by influences working automatically on the price level through changes in the quantity of gold within that nation. If gold is withdrawn, prices fall, exports of goods are increased, and in due time the gold begins to return until the country's quota of gold reaches an equilibrium adjusted to the relative demands of other countries. The movement of goods forms the variable in the process which aims at a correction of the quota of gold, whenever the equilibrium has been disturbed. The shipment of gold is the initial cause; the movement of goods is a consequence.

In support of this view—the orthodox view—it is held that gold will flow wherever its exchange value is highest. The flow of gold will make it abundant in the receiving nation, and thus, because it is cheap, will raise general gold prices there; or, *vice versa,* will lower prices in the countries from which gold is taken. The possession of

the proper amount of gold seems to be the main consequence, while commerce is regarded as the means to the end.

This manner of treating the problem, however, reverses the true order of events. Commerce is the real objective which lies behind all other phenomena, such as the methods of payment; the movement of money is a secondary operation, dependent on the direction and extent of the shipment of goods. Moreover, to say that gold, like other goods, flows where its exchange value is highest, is a truism; the real question to be settled is, how does the flow of gold take its effect on prices? To say that because it is abundant it raises prices is to assume the whole problem at issue. How does a cheapened mass of gold adjust itself to other goods? What is the price-making process? Are goods priced only by an actual exchange of those goods against the increasing flow of gold? On this point the adherents of the orthodox teaching of Ricardo have offered no light.

The trouble with many symmetrical monetary theories is that they do not agree with the facts. For instance, it has been pointed out that the gold stock of the United States has increased three and one half times from $326,000,000 in 1880 to $1,174,000,000 in 1902; and yet that gold prices in the United States in that period have fallen. This discrepancy between fact and theory is dogmatically disposed of by assuming that the growth of our trade has outstripped the supply of gold. This position is far from tenable; there are no statistical data in existence worth a fig, which could give us the truth as to the money-work, or demand, for gold. To say that our gold has increased at all only because of our phenomenal increase in trade relatively to other countries is to make a statement without proof. Possibly our deplorable silver legislation of the past has forced us to carry more gold than we ought to have held; just as men on the frontier must invest considerable means in firearms for protection from purely local dangers. Other countries than ours have enormously increased their trade, but they have not added in the same proportion to their gold circulation. In truth, the old-fashioned theory on international price-changes needs restatement in vital parts. It will be found that forces affecting the prices of goods, such as demand and supply of those goods, are of primary influence in affecting prices, quite independent of the action of a medium of exchange—which chiefly comes into existence, in fact, as a consequence of the exchange of goods. The movement of specie is not the end of commerce, but specie moves as an instant consequence of commerce. The monetary changes follow, and do not precede the operations in merchandise and securities.

VI. *Bimetallism.*

Bimetallism was eagerly taken up by writers as a means of increasing what was once regarded as a deficient supply of the world's metallic circulation. The decline of prices,—which in this country began in 1866 and not in 1873—was attributed to a scarcity of 'money' throughout the world. Therefore, if silver could be added to, or retained with, the circulation of gold, the larger quantity of metallic money would, it was believed, support, or even raise, the general level of prices. The theory of prices, assumed as a matter of course in this exposition of bimetallism, was the quantity-theory.

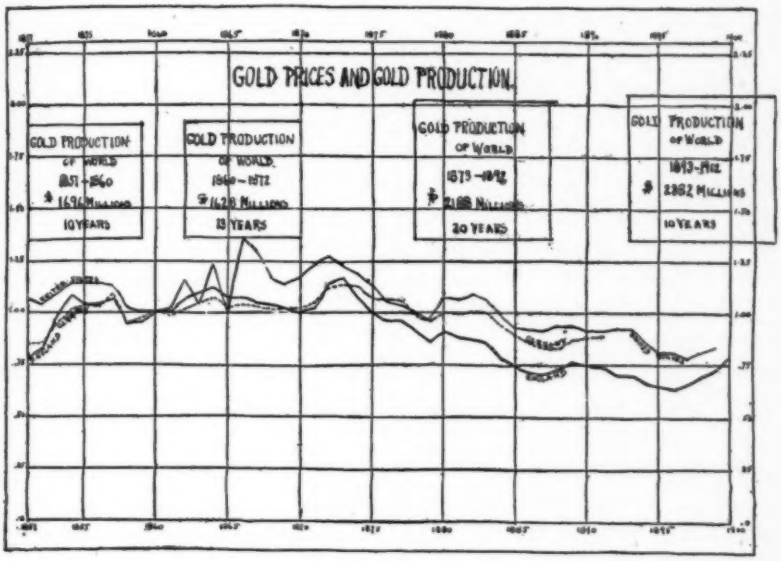
Throughout the recent writing and speaking on monetary topics, in both Europe and America—if not also in Asia—there has been a very general subsidence of interest in bimetallism. The demand for silver has been believed to be unnecessary because of the enormous production of gold in recent years. That is, by the old quantity theory on which bimetallism was based, some authorities—and more politicians—have saved their consistency by accepting the gold standard.

The logic and character of bimetallism can not escape so easily. If the quantity-theory falls, the whole artificial structure of bimetallic argument falls; and the gold standard can not possibly be supported by intelligent minds on any such basis of theory. The facts are too ugly. In the accompanying diagram it must appear to the most casual student that if the fall of prices on or about 1873 was due to a scarcity of gold, then not only because the supply of silver has been greatly increased, but especially also because the supply of gold has been about quadrupled since 1850, we ought to have witnessed a phenomenal rise of prices in the last decade or two. The movement of prices on the diagram, however, has been generally downward, or at least not seriously rising, during all the years when the production of gold has been so astonishingly large. The facts oblige us to question a theory which presents such evident disparities as this; and one is obliged, in all fair-mindedness, to accept the truth that many other and potent influences, besides the quantity of the media of exchange, have a powerful effect upon the price-level. When this admission is made, then the investigator is in a position to understand the remarkable influences of the great industrial revolution of the last thirty years upon the expenses of production of all articles, and hence upon their market prices. Thus, the sweep of economic forces, in the natural tide of events, is bringing us to a saner and very different point of view than that of the scientific bimetallist of past years.

VII. *Stability of Exchange.*

Consistency is a jewel; but it may be questioned whether it is always worth the price. The escape from the pitfalls of bimetallism

and the quantity-theory has led to some new and surprising formulations. It has been the hope of the bimetallists to secure a parity of exchange between countries now using gold and silver standards. If gold could be maintained permanently at a given ratio with silver, this happy result might have been brought about. It is needless to say that bimetallism proved to be a political impossibility, even in the countries of the Latin Union. By force of business requirements, such



silver as has remained in general circulation was effectively kept at a value in gold equal to its face value by varying devices in different countries, all of which had a common principle—practically equivalent in a more or less evident form of redemption in gold. In the case of India, it is frankly accepted that the value of the rupee has been maintained at a fixed price in gold by a machinery which amounts to the establishment of the gold standard, involving a quasi-redemption of silver rupees in gold at 16*d.*

If, however, there are some silver-loving sensibilities to placate, such a process is not spoken of as the establishment of the gold standard through the indirect redemption of inferior silver by gold, but it has been discovered that a uniform ratio of exchange between gold and silver-using countries can be established, not by the gold standard, but by a 'gold-exchange standard.' In the recent proposals laid before Mexico and China this new form of statement has been employed. It is difficult to know what the new term means. A bill of exchange in a silver country drawn on a gold country is nothing

but the amount of silver coins of the one nation which must be given to buy a stated sum of gold coins of the other nation. The silver bill varies relatively to gold coins in proportion to the changes in the value of silver bullion relatively to gold—unless the silver coins, under the laws of token-money, are kept at an artificial value, above the market value of the silver bullion in them, by some method, more or less direct, of redemption in gold. When silver bills are offered in the exchange market, they are simply offers for the sales of so much silver to be paid for in gold. If, then, the treasury of the silver-using country buys the bills, in certain emergencies of the exchange market, it is paying gold for silver; or, in other words, it is to that extent redeeming amounts of silver in gold.

Stripped of its enveloping mystery, the only way in which the new proposals for Mexico and China can establish stability of exchange is to establish the gold standard. For that purpose, if the silver coins in common use are to be rated in gold above the market value of the silver content of the coins, the only way in which parity in daily business, or in the exchanges, can be maintained is by creating a gold reserve large enough to redeem coins at par, or buy exchange at par, if no direct redemption is allowed. The whole operation, therefore, harks back to the principles regulating the value of such money as token-coins, bearing a seigniorage, or paper money, which has no value in itself. The worship of quantity as a regulator of value of money may do for those who are unwilling to test their theories by the facts; but inevitably one is obliged to admit that other forces are far more potent than quantity.

VIII. *The Value of Paper Money.*

I have said that the pivotal problem in the whole field of money is the theory of prices or the value of money. How true this is may be seen by the recurrence of this issue in each of the problems noted in this paper; and in the last one which I shall take up it again reappears. What regulates the value of those forms of money which circulate at a rate above their content is a question which forces itself to the front whenever we study a case of paper money. In times past, it has been sufficient to explain the value of paper money by referring its rise or fall to an increase or diminution of its quantity. This blind reliance on quantity as the main force controlling the value of money can not now, with our knowledge of the facts, be consistently held.

The amount of notes which a merchant can put out, provided he redeems them promptly, is limited only by the extent of his transactions. So it is with a nation. Given a certain set of business operations, as many notes can be kept in circulation as are needed by the

community, and no more; and these notes will remain at par only if there is a recognized system—not of ultimate, but of immediate redemption. No matter what quantity of notes may be put out, if there is no system of immediate redemption, the notes will depreciate. But, if there is an effective system of immediate redemption in operation, then no matter what the amount issued, none of it can depreciate, and only that quantity which is needed by the convenience of the business public will remain outstanding. In this way it may be realized that the element of quantity is incidental to the more dominant factor of redemption.

The connection of the value of the standard money with the paper promises to pay in that standard coin is the one important consideration in determining the value of paper money. Redemption is the only sure means of ascertaining automatically what quantity of paper is needed by the public. Redemption determines both the quantity and the value of the paper.

In the case of irredeemable paper, however, it is often assumed that, in the absence of redemption, the value of the paper is determined directly by the amount outstanding as compared with the uses to which such money can be put. There is believed to be an imperative demand for money, as a medium of exchange, which must be satisfied in some way; and in default of anything better, irredeemable paper will be required, and a value will be given to it by this imperative demand. Then, only if issued in excess of this demand, will even irredeemable paper depreciate. This is the usual explanation of the fact that irredeemable paper, worthless in itself, bears any value at all.

THE VEGETABLE FIBERS OF THE PHILIPPINE ISLANDS.

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THERE is probably no country of equal size in the world having a greater variety or wealth of vegetable fibers than the Philippine Islands. These fibers are of every class and of every description. They are obtained from the bast of the largest forest trees and from the slender stems of twining ferns. Their uses range from the manufacture of the most delicate and beautiful of textile fabrics to the construction of cables, furniture and houses. As an article of commerce, the one fiber, manila hemp, exceeds in value the combined values of all other products of the islands. As a factor in the domestic economy of the Filipino people, the fibrous plants of field and forest furnish, with the exception of food, nearly all the necessities of life.

The Relative Importance of the Fiber Industry.

The relative position that the vegetable fibers hold among the various agricultural products of the Philippine Islands is a subject that is neither clearly nor generally understood. The development of the various branches of the fiber industry will, in no inconsiderable degree, determine the future industrial condition of the islands. Until very recently there has been practically no machinery, no modern methods of cultivation, no introduction of improved species and varieties of plants; and yet, even under these unfavorable conditions, the production of fiber has grown to be the leading industry of the islands. To-day the vegetable fibers and fiber products form the most important source of wealth of the archipelago. A brief investigation of several of the more important of the fiber-producing plants should be sufficient to give some little idea of the vegetable fiber in the Philippines as a commercial product. Such an investigation, however, must leave entirely out of consideration the greater part of the four or five hundred so-called 'local' fibers, the use of which plays an interesting and important part in the every-day life of the Filipino. To fully appreciate the extensive use of these local fibers, one must go into the fields and villages and homes of the native people.

But two fibers are now exported from the Philippine Islands, manila hemp and maguey. The latter has been, up to the present time, of comparatively little importance; the annual exports of maguey fiber amounting to something more than one thousand tons. Manila hemp, however, is not only the leading article of export, but it con-

stitutes more than two thirds of the total value of all exported products. Its position is indicated by the following table.

EXPORTS FROM THE PHILIPPINE ISLANDS FOR THE YEAR 1903.

Article.	Value.	Per cent. of Total Exports.
Manila hemp	$21,701,575	66
Copra	4,473,029	14
Sugar	3,955,568	12
Tobacco	1,882,012	5
All other	1,109,596	3
	$33,121,780	100

The production of manila hemp is a well-established and very profitable industry, the development of which requires only an improvement in methods of cultivation and the introduction of fiber-extracting machinery. Maguey is a comparatively new product, and its value is not as yet well known throughout the islands. Cotton and kapok (tree cotton) are widely distributed and have a general local use. Coir (cocoanut fiber) is produced in enormous quantities, but is not utilized, because of the lack of fiber-extracting machinery. Jute grows in several of the provinces, but is not produced in quantities sufficient for export. These six vegetable fibers, which are among the most important commercial fibers of the world, are all Philippine products, and can be economically and profitably produced throughout the archipelago.

Classification of Fibers.

Vegtable fibers may be classified either according to their structure or to their uses. The former classification includes the 'bast fibers,' obtained from the inner bark of dicotyledonous plants; the 'structural fibers,' obtained from the stalks, leaf stems and leaves of monocotyledonous plants; the 'surface fibers,' or hair-like growths surrounding the seeds of certain plants, and the 'woody fibers,' consisting of the whole or a part of the stems, roots or wood of various plants.

Any economic classification is unsatisfactory for the reason that the same fiber frequently has several entirely different uses. Thus, for example, manila hemp, primarily a cordage fiber, is extensively used in the Philippines for textile purposes; while cotton, a textile fiber, is also used for cordage. Considering only their more important uses, we have the following general economic divisions, together with one or more of the leading Philippine fibers of each division.

Cordage fibers.
- Abacá.
- Maguey.

Textile Fibers.
- Cotton.
- Piña.

Stuffing and Filling Material.
- Kapok (tree cotton).

Plaiting and Thatch Material.
- Nipa.
- Burri.

Tie Material.
- The Rattans.
- Malobago.

Abacá (Manila Hemp), *Musa textilis.*

The fiber produced by the plant *Musa textilis* is known throughout the civilized world as manila, or manila hemp. In the Philippine Islands the name abacá (pronounced ab-a-kár) is applied to both plant and fiber. This fiber is distinctly a Philippine product, for the abacá plant, though introduced into India, Borneo and other countries, has never been successfully cultivated other than in the Philippine Islands. Manila hemp was first exported from the Philippines a century or more ago. In 1820 samples of the fiber were brought to Salem, Massachusetts by John White, a lieutenant in the United States navy, and from 1824 to 1827 it began to be used quite extensively in Salem and Boston. The growth of the industry is indicated by the increase in exports of fiber, from 41 tons in 1818 to 137,752 tons in 1903.

The common banana, *Musa sapientum,* the plantain, *M. paradisiaca,* and abacá, *M. textilis,* are closely related species of the same genus. The banana plant produces a fiber similar in appearance to manila hemp, but lacking in strength; while the fruit of abacá resembles the banana, except that it is filled with large black seeds and has no economic value. The abacá plant is a large tree-like herb fifteen to twenty-five feet high, a single rootstock bearing from twelve to twenty stalks. These stalks, from which the fiber is obtained, are formed of a series of thick, fleshy, overlapping sheaths, each sheath being the petiole of a leaf.

At the time of flowering, which occurs when the plant is from two and a half to three years old, the stalk is cut close to the ground and the leaves are removed. The native laborer, sitting on the ground, inserts under the bark or fibrous covering of one of the outer leaf sheaths a small piece of bone called the 'locnit,' and with it tears off a long ribbon-like strip of fibrous material. Each successive layer is similarly treated down to the central stem of the trunk. The fiber ribbons are collected in the field and are taken to a small bamboo hut where the fiber extracting apparatus has been set up. This crude machine, the 'panguijan,' consisting of a large knife fastened upon a block of wood and operated by means of a bamboo spring and foot lever, is the only method that has ever been discovered for extracting manila hemp. The work of hemp-stripping is very exhausting, the average result of a day's work being about twenty-five pounds of fiber. The record of the numerous attempts and failures to perfect an abacá-cleaning machine forms one of the most interesting chapters in the industrial history of the islands. The introduction of such a machine will be of almost incalculable benefit and will revolutionize the entire hemp industry.

The only treatment of hemp, after the completion of the stripping process, is a few hours' drying in the sun. The fiber is then made up into rough bales and packed over the mountains, or shipped in native boats down the rivers, to the nearest seaport. From here it is taken

in a small coastwise steamer to the baling presses and warehouses of Manila and Cebu.

Maguey, Agave sp.

Several different species of the genus *Agave*, including *A. Americana*, *A. vivipara* and *A. rigida*, are found in the Philippine Islands. Both the plant and fiber are known throughout the archipelago as 'maguey'; while the fiber, in the commercial world, bears the name 'Manila aloe.'

This plant was probably first brought to the Philippines from

FIG. 1. STRIPPING ABACÁ.

Mexico or Central America; but when, or by whom, there are no records to determine. It is now grown on all of the larger islands, and as a fiber producing plant is next in importance to abacá. Maguey fiber is used locally in many of the provinces both as a cordage and as a textile material. It is produced in sufficient quantities for export only in the provinces of Ilocos and Union of northern Luzon. In this district rice and corn are cultivated in the more fertile fields, the stony hillsides and other so-called 'waste land' being utilized for maguey. For several reasons maguey seems destined to become an important Philippine product. It is not seriously injured by the long dry season, it can be successfully grown on 'light,' dry soils, and its cultivation requires comparatively little labor and but few draught animals, all of which characteristics make it eminently suited to conditions found in many parts of the islands.

The maguey plant consists of a short thick stem which bears an

aloe-like cluster of from twenty to forty fleshy leaves. These leaves are light green in color, bear sharp lateral teeth and a terminal spine, and are from three to five feet long. The leaf is composed of pulpy material interspersed with the vascular bundles which furnish the fiber. When the plant matures, which requires from seven to fifteen years, a central stalk, or 'pole,' grows to a height of fifteen to twenty feet. This stalk first bears flowers and afterward a large number of small bulbs. The growth of the 'pole' is followed by the death of the plant.

The process of fiber extraction consists in separating the fibro-vascular bundles from the pulpy portion of the leaf. Where machines are used for this work, the leaf is run under the surface of rapidly revolving wheels or rollers which scrape the pulp from the fiber. In the Philippines the fiber is extracted by the process known as 'retting.' The mature leaves are harvested and tied in bunches. These bunches are then placed in the streams and rivers, where they are allowed to remain under water for eight or ten days. This 'retting,' or rotting, results in the disintegration of the substances which surround the filaments. After the leaves have been sufficiently retted they are removed from the water, dried in the sun, and are then shaken and beaten to remove all extraneous material that may still adhere to the fiber. This retting process is slow, expensive, and gives an inferior quality of fiber. Improved fiber-extracting machinery has recently been imported into the Philippine Islands and the general use of such machinery should give a decided stimulus to the maguey industry.

Cotton, Gossypium sp.

Cotton has been grown in the Philippine Islands for hundreds of years. In 1601 three hundred pieces of 'Ilocos cloth' were sent from Manila to the Moluccas, and throughout the earliest Spanish records of the islands we find frequent references to cotton and cotton-growing. At one time the production of this fiber occupied a position of considerable importance and domestic cotton was an article of inter-island trade, but the importation of cheap cotton goods was followed by a decline of the local industry and it has never regained its former position. The Spanish authorities endeavored to foster the industry by means of ordinances and government regulations, but without any appreciable results. To-day we find small 'patches' of cotton scattered throughout the islands from northern Luzon to southern Mindanao. Occasional shipments of a few bales each are received every year in Manila, principally from the province of Ilocos. In many different towns and villages small quantities of cotton are collected, cleaned by hand and woven into a coarse cloth. There is nothing in the archipelago at the present time, however, worthy of being called a cotton-growing industry.

There is every reason why the cultivation of this plant should be

encouraged, as cotton and cotton goods form one of the largest items of imports into the islands. Experiments that have been made during the past year, to say nothing of earlier efforts in the same direction, have demonstrated that a satisfactory yield of good cotton can be obtained in the Philippines. Insect enemies will have to be overcome and methods of cultivation regulated to suit an early or late rainy season, but, in general, soil and climate conditions are favorable. A great deal of interest is now being shown in regard to this subject by Filipino planters. Large quantities of seed have been distributed in the provinces, and the next year promises to show at least a begin-

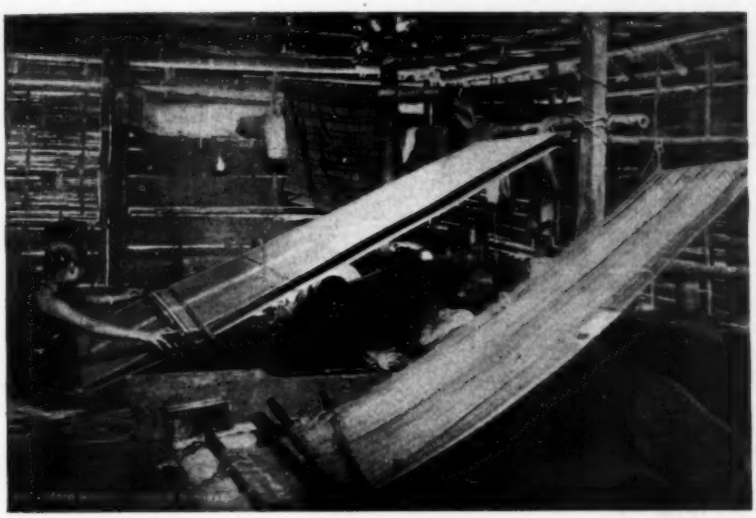


FIG. 2. MORRO WOMAN WEAVING SARONG.

ning towards the establishment of a Philippine cotton-growing industry.

Piña (Pineapple), Ananas sativa.

Pineapple fiber, or piña, is of peculiar interest as furnishing the material for the beautiful and justly celebrated piña cloth. This fiber is obtained from the leaves of the same plant that produces the well-known fruit. The pineapple plant is grown quite extensively in the Philippine Islands both for its fruit and for its fiber, but when utilized as a fiber plant the undeveloped fruit is usually cut shortly after the time of flowering.

Pineapple fiber is one of the finest and strongest of all of the vegetable fibers. It is the former quality that prevents its more extensive use, as the extreme delicacy of piña makes its extraction from the leaf an extremely slow and difficult operation. A very simple and primitive method is used in the Philippines for the extraction of this

fiber. A single freshly cut leaf is placed upon a smooth board and is then scraped with an old plate or piece of earthenware. This scraping removes the pulpy material and lays bare a layer of fiber which is deftly lifted with the finger or a small spatula. After the fiber has been thus extracted it is washed in running water and dried in the sun. Frequently the washing and drying are repeated several times before the required degree of softness and fineness is obtained. It is estimated that twenty-one thousand leaves are required to produce fifty pounds of fiber. When it is considered that each separate leaf must be slowly and laboriously scraped, the small production and high price of piña fabrics are not surprising. Before piña can become a product of any considerable commercial importance, a machine must be perfected for the extraction of the fiber.

Kapok (Tree Cotton), Ceiba pentandra.

The white cotton tree with its tall straight trunk, its almost horizontal branches, and large odd-looking seed pods is well known to any one who has traveled through the Philippine provinces. This tree is found in nearly all parts of the tropical world. In Java there are extensive kapok plantations, but in other countries we usually find the cotton tree growing along the roadsides, scattered through the forests; or, as in India, planted about the old Buddhist temples. There are no kapok plantations in the Philippines, but the cotton tree grows in nearly all of the provinces and the fiber is very generally used for local purposes.

Kapok is the floss obtained from the seeds of the cotton tree and, in a structural classification, is one of the 'surface fibers.' The fiber is too short a staple, and also too brittle and elastic, to be spun, but these very properties make it the most valuable of all the vegetable fibers as a stuffing and filling material. Its harshness and elasticity prevent its becoming matted when used for cushions, pillows and mattresses. For bandages and surgical dressings it is cooler and more elastic than cotton.

Not only does the cotton tree produce a valuable fiber, but it has, also, a number of other economic uses. The tree itself, with its horizontal branches, is used for living telegraph poles and as a shade tree on coffee plantations. The wood, which is light and soft, is utilized for tanning leather and for making toys. The sap and tender leaves have a medicinal value. The bark yields a reddish fiber from which cordage and paper are made. The roots, when powdered and mixed with the sap, is a cure for dysentery. The fruit has some value as a food product. The seed yields an excellent oil and the seed cake is used both for cattle-feeding and as a fertilizer.

In Java the production of kapok is rapidly becoming a leading industry, and this fiber is getting to be more generally known and more

fully appreciated throughout the civilized world. The more extensive cultivation of the cotton tree in the Philippine Islands is greatly to be desired, as the development of this industry will add another valuable commercial fiber to the list of our exported products.

Nipa, Nipa fruticans.

One of the most widely known of all Philippine objects is the nipa house, or 'shack.' The material used for the construction of this house is the fibrous leaf of the nipa palm. This palm grows along the shores and in the deltas of rivers. Its leaf, consisting of a long

FIG. 3. THE BURRI PALM.

midrib bearing a large number of slender leaflets, is similar in structure and appearance to the leaf of the cocoanut. When the plant is fully grown the leaves are cut and the leaflets stripped from the stem. These leaflets are bent over a piece of bamboo, sewed together with fine strips of rattan, and thus made into small mats or shingles. The nipa mats are laid on the sides and roofs of houses in the same manner as shingles, and are fastened down with strips of bamboo. A house built of this material can be constructed in a few days and, under ordinary conditions, will last from five to seven years. It is cheap, cool and in every way suited to the climatic conditions of the country.

The nipa palm has several other uses. Its fruit is edible and the

flower stem yields an alcoholic beverage known as tuba or nipa wine. Hats, mats, rain coats, sails and various other articles are woven from the leaves.

Burri, Corypha umbracullifera.

Another member of the Palmaceæ that has a great variety of uses in the Philippines is the burri, or talipot palm. This palm grows in abundance in nearly all parts of the archipelago. It is a large ornamental tree crowned with gigantic fan-like leaves. These leaves, like those of the nipa, are composed of numerous slender leaflets. In the burri, however, all of the leaflets radiate from the end of the long stem. Preparatory to use, the leaves are gathered and dried, often for several weeks. They are then split into narrow strips and in this form are woven into hats, mats, bags, baskets, fans and other similar articles.

Local Fiber Plants.

More than four hundred Philippine plants have been reported, the fibers of which have some local economic use. It is difficult to select from among this number the few that may be considered of first importance. The rattans (*Calamus sp.,*) which are found throughout the forest regions of the islands are of great value and are used for many different purposes. Malobago, or balibago (*Hibiscus tiliaceus*), is a valuable bast fiber obtained from a tree growing near the seacoasts. Pangdan (*Pandanus* sp.), the plant known in the United States as 'screw pine,' yields a fibrous leaf from which are made hats, mats and sugar-sacks. Idioc, or cabonegro (*Caryota urens*), is a coarse black fiber well known in the commercial world and used in the Philippines for making a coarse resistant cordage. Anabo (*Abroma alata*) is a strong fine bast fiber produced in all parts of the archipelago and largely used as a cordage material.

The Development of the Fiber Industry.

The methods now employed in the production of the leading Philippine fibers are slow, wasteful and a century behind all ideas of modern agricultural development. Certain definite lines of improvement such as the more careful selection of plant varieties, a more thorough system of cultivation, and the extraction of fiber by means of machinery are urgently needed. A development of the fiber industry along these lines, that shall result in carefully managed abacá, maguey and cotton plantations, and in the introduction and general use of fiber-extracting machines, will be a long step towards the fulfillment of the first and greatest need of the Philippine Islands, the establishment of the country on the solid basis of material prosperity.

THE CLIMATE OF THE CENTRAL AMERICAN PLATEAU.

BY GUSTAVE MICHAUD, D.Sc.,
SPRINGFIELD, MASS

A FEW weeks ago the *Springfield Republican* published the following extract from a letter sent by our minister to Costa Rica, Hon. W. L. Merry, to Gen. G. W. Davis, governor of the Panama canal zone:

> Six years and a half of residing in San José have made manifest to me its fine and agreeable climate. When this fact will be known to the many American officials and employees coming to the Isthmus of Panama to work under the canal commission, they will take advantage of the opportunity to visit Costa Rica for recreation and for their health. . . . A few weeks stay here would invigorate our men.

The writer spent six years, from 1889 to 1895, on the Central American plateau and gathered some meteorological and physiological data which led him to the conviction that our minister's statement is not exaggerated. The climate of that portion of the upland which extends from the Panama isthmus to the Yucatan peninsula, and which includes the highlands of Costa Rica, Nicaragua, Honduras and San Salvador, has features of its own, not frequently found under the tropics and never outside of them.

The uniformity of temperature throughout the year, which characterizes the tropical climate, an altitude of some 4,000 feet above sea-level, with its corresponding decrease in the density of air, a lower temperature than could be expected for such an altitude in the torrid zone, are the main features of the climate of the Central American plateau. The last of these is the most important. The value of tropical plateaus as health resorts is a subject which has been much discussed recently. That of the Central American upland will be better understood if some of the conclusions which have been reached within the last ten years, as well as some of the experiments which have led to these conclusions, are previously stated.

The density of air decreases rapidly as one rises on a mountain slope. At an altitude of 18,500 feet, a given volume of air contains but one half the quantity of oxygen which it contains at sea-level. Scarcity of oxygen does not seem to be a desirable condition, yet recent experiments have shown that, within certain limits, that very quality of mountain air induces in the human system changes which

are beneficial to the majority of patients. The most important of these can be briefly stated: The number of the blood red corpuscles increases as the air becomes rarer. The main office of the red corpuscles is the absorption of oxygen in the lungs and the carrying of it into the whole body, wherever heat and power are to be generated. There are over two millions red corpuscles in one drop of the blood of a healthy person. In anæmia and connected states, that number often falls to one half of its value. Life in rarefied air results in the opposite state. After the adaptation period is over, a considerable increase in the number of red corpuscles, coinciding with more frequent and deeper aspirations, causes the paradoxical result, that more oxygen is brought to the organs in the rarefied mountain air than in the denser medium, at sea-level.

NOON AT THE VILLAGE MARKET, COSTA RICA.

The scientist, Viault, was the first to notice that there was an extraordinary number of red corpuscles in the blood of the inhabitants of the high plateaus of Peru. Careful determinations led him to the conclusion that the average increase was from 5,000,000 per cubic millimeter in the blood of a man living at sea-level, to 8,000,000 after a stay of three weeks at an altitude of some eight thousand feet. In their book, *La vie sur les hauts plateaux,* the Doctors Herrera and Lope, of the city of Mexico, reached a similar conclusion. In Europe, Egger experimented on Monte Rosa (6,201 feet), and found that the red corpuscles increased, on the average, 17 per cent. in two weeks. Karcher, Sutter, Veillon, experimenting on lower altitudes (3,452, 3,232, 2,297 feet), still found a notable increase of the red corpuscles. Wolff and Koeppe noticed it again on the Reyboldsgrun, which is only 2,300 feet high. In 1896, Leuch published in the *Korrespondenzblatt f. Schweitzer Aerzte,* the results of a most accurate and painstaking study on the changes undergone by the blood of anæmic school chil-

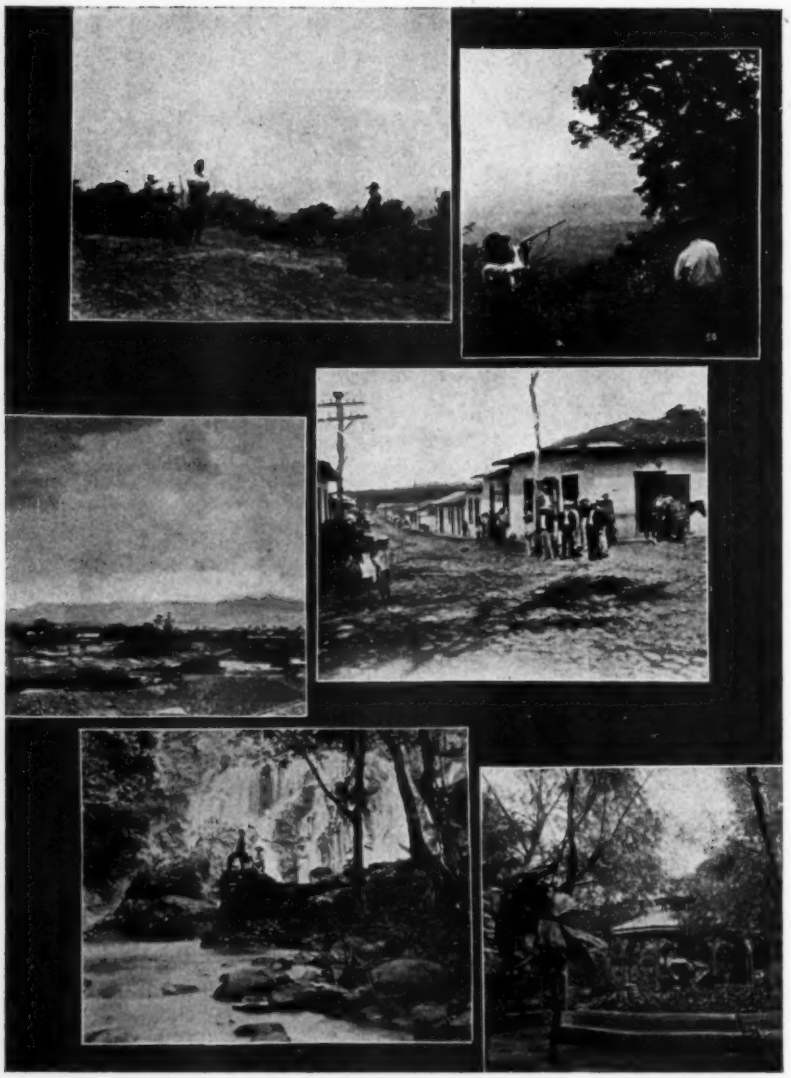
SHADE AND LIGHT EFFECTS AT A HIGH ALTITUDE, CARPENTERIA MOUNTAIN.

dren after a stay in the mountains. The anæmia disappeared, while the number of red corpuscles increased. It decreased after return to a lower level, but remained higher than before the sojourn on the mountain. These facts were fully confirmed by the researches of Mercier, von Jaruntowsky and Schroder.

The greater consumption of oxygen induced by the increase in the number of red corpuscles has been measured. According to Schumberg and Zuntz, a man brought to an altitude of 12,467 feet consumes 33 per cent. more oxygen than at sea-level. The increase is not instantaneous. Coindet found that foreigners who had but recently arrived on the Mexican plateau inspired 5.5 liters per minute, while those who had spent a longer period in the same localities took in nearly 6.5 liters.

But while the adaptive changes take place readily and regularly under ordinary conditions in healthy persons, many observations at health resorts of high altitude have shown that in a few cases (old age, certain organic diseases of the heart) they do not take place at all, while in the case of anæmic and neurotic patients they take place only at a moderate altitude and when a cool and bracing atmosphere allows of much outdoor exercise without perspiration. A natural inference to be drawn from those facts is that the climates of all tropical plateaus are not equally conducive to health. While all of them allow life outdoors in any season, and, when not extremely high, are absolutely free from the considerable and sudden changes of temperature which are so injurious to consumptives in the temperate zone, yet the value of such resorts depends mainly on the grade of cooling attending the ascent, especially in the case of general debility, constitutional or even symptomatic. Extremely high altitudes do not agree with the majority of patients; if, at a moderate height (from 3,000 to 5,000 feet), the temperature is low enough to invite exercise, the climate is certainly curative. But if the thermometer reaches daily the eighties, the heart will be unduly quickened during exercise, perspiration will become visible, a tired feeling will appear and the hematose as well as the genesis of blood corpuscles will be interfered with. To suffer from the heat while taking exercise is never invigorating, but, in rarefied air, it is an inconvenience which is the more serious in proportion as the altitude at which it manifests itself is greater. It may be said that, other circumstances being equal, the invigorating value of the climate of a tropical plateau depends on the amount of cold bought at the expense of air rarefaction.

This fact gives the climate of the Central American upland its superiority over that of the broader portion of the plateau which extends from Guatemala to California and which includes the whole Mexican tropical highland. The average yearly temperature of San



11,500 FEET. SUMMIT OF VOLCANO IRAZU.
7,000 FEET. ON THE SIERRA CANDELARIA.
5,000 FEET. A STREET IN SAN RAFAEL.
3,800 FEET. A STORM ON THE VOLCANO IRAZU.
2,500 FEET. RIO BRAZIL.
SEA LEVEL. A PUBLIC GARDEN IN PORT LIMON.

José is 67.5°; that of the sea coast is 78.0°. These figures show an average decrease of temperature of 2.8° for every 1,000 feet of altitude. Observations made in other Central American cities, though less reliable, give even higher figures. On the Mexican tropical plateau, the average decrease of temperature resulting of the ascent is only 2.3°

per 1,000 feet. This average is based upon the study of the climate of the cities of Puebla, Mexico, Guadalajare, San Luis Potosi, Pachuca, Zacatecas, Guanajuato, Oaxaca, Queretaro, Aguas Calientes, Leon, Pabellon, San Juan del Rio, Patzecuaro, Tacubaya, the list including all the cities situated on the tropical plateau and for which meteorological records are available. The highest figure (2.7°) is given by the city of Zacatecas, 8,187 feet high; the lowest (1.8°) by the city

FOUR TYPES OF COUNTRY HOUSES ON THE CENTRAL AMERICAN PLATEAU.

of Oaxaca, which, although standing 1,349 feet above San José, has a warmer climate (69.0°) than the latter city.

There are in Central America but two seasons: the rainy season, extending from about the middle of May till the middle of November, and the dry season, covering the rest of the year. In the rainy season, rain falls only for a few hours every day, generally from 2 p. m. till 6 p. m. leaving both mornings and evenings cloudless. Patients suffering from lung troubles find both seasons about equally curative on the highland. Debilitated and neurasthenic invalids recuperate better in the dry than in the rainy term. During the rainy season, the cities situated on the Atlantic slope have a climate somewhat dryer than that of the cities which are located on the Pacific side. The contrary is true during the dry season.

The intensity of light, a result of altitude and latitude combined, is perhaps one of the most important therapeutic elements of the climate

of many tropical uplands. Thanks to the researches of Pettenkofer, Voit, and especially to the heliotropic experiments carried on a large scale by Finsen at the Light Institute of Copenhagen, we begin to realize that the chemical rays of sunlight have as much to do with nerve action and metabolism as with sunburn. So far as the latter phenomenon is concerned, the worst sunburn the writer ever saw . . . and felt . . . was got *through a colored shirt,* in the neighborhood of the city of San José. About 8,000 or 10,000 feet, it is impossible not to notice the extraordinary intensity of solar illumination when the sun is nearing the zenith. At a much lower altitude, in the case of such subjects as 'Noon at the village market,' the photographer soon learns that times of exposure which gave the best results in the United States give overexposed negatives on the Central American plateau.

From one of the scientific periodicals published in the progressive little republic of Costa Rica, *El Boletin del Instituto Fisico-Geografico,* the writer compiled the following summary of the climatic conditions of the city of San José. The *Boletin* is published by the government meteorological observatory, an institution founded in 1889 by that remarkable Costa Rican, Don Mauro Fernandez, who was then Minister of Public Instruction. The observatory has a staff of four scientists and has rendered considerable service to the study of the climatology of that quarter of the world. The data represents the average of observations extending over a period of twelve years.

	Dry Season, December to April, Inclusive.	Rainy Season, May to November, Inclusive.
Temperature 2 a. m.....	62	63
" 6 a. m.....	60	62
" 10 a. m.....	72	73
" 2 p. m.....	77	76
" 6 p. m.....	68	68
" 10 p. m.....	64	65
Daily average.....	67	68
Rain, inches.....	4	71
Relative humidity	75	84

THE SCIENCE PROBLEMS OF THE TWENTIETH CENTURY.

BY PROFESSOR A. E. DOLBEAR,
TUFTS COLLEGE.

LET us define science as knowledge of the relations of phenomena, and define phenomena as any or all changes that take place, which may be known to mankind. Let us also assume uniformity of action, that is that under assigned conditions the same phenomenon will be reproduced, what is called and what is meant by the term *law*.

We have several bodies of correlated relations which constitute such sciences as astronomy, chemistry, biology and so on. The phenomena exhibited by large bodies at great distances apart we call astronomy. Such as are exhibited by minute bodies near together we call chemistry, and the phenomena among living as distinguished from what we call dead things, we call biology. Among these and other similar sciences, where we have noted the uniformities in the phenomena and find ourselves able to predict occurrences, we say we have definite knowledge, and especially so when the bodies that exhibit the changes are of such magnitude that we may control them. This is what is meant by experimentation. Until phenomena are studied in their relations to other known and established relations they can not be said to be a corporate part of science. There are many isolated facts not yet in established relations, awaiting their proper setting. Facts are always scientific data, they are not science itself. That a body left unsupported will fall to the ground has been known for thousands of years, also that the moon revolves about the earth. The correlation that shows that both belong to the same class and are due to the same agency, gravitation, is science. The man who proved the relation was a scientific man, was doing scientific work. In like manner everybody has known in all times, of mankind and animals on the earth. The correlations that show their relationship is science, and the one who showed it was a scientific man. The two examples are to show that scientific work consists in establishing the relations among phenomena. This is what marks the profound difference between the work of the nineteenth century and all the preceding ones—the establishment of the relations among phenomena.

Prior to the nineteenth century there was a vicious assumption underlying nearly all effort in the domain of knowledge, that was, that there were no necessary relations among the different classes of phe-

nomena. That astronomy, geology, physics, chemistry, physiology and all the rest were independent departments of knowledge and that each could be worked out completely without help or hindrance from others. The great contributions of the nineteenth century showed they were all of one family, and the surprise as one after another were thus linked was only paralleled by the hostility manifested in many quarters to such a claim. Together they show strongly that the knowledge was so unexpected and so new that it was not easily assimilated. Especially was this true when the new implications made it needful to abandon much in philosophy and religion that had been held to be unassailable. Many heated battles were fought, but science was always victorious and never had to surrender a field once entered.

What these triumphs were has often been presented within a year or two, and the recital of them has raised the query in many minds whether there can possibly be left much of importance to be discovered. Alexander conquered the world and wept because there was no more Alexandrine work to do. He must go home and mope the rest of his life. Inactivity is an intolerable idea to an energetic man with but one idea. Heaven saved Alexander from a long endurance of such idleness as he feared, by removing him when his work was done.

Is there no more work for the man of science? Are there no more problems of importance awaiting the investigator? Have we all the knowledge we are likely to get? There are some who, having noted the prodigious product of the nineteenth century, have half feared that science has been worked out.

That this is not true I will endeavor to show.

Beginning with astronomy. We are well assured now that the earth as a part of the solar system has had a long history. That all these bodies have reached their present conditions and relations by a process of growth taking millions of years. The same factors that have been active in the past are still operative, producing changes in magnitude, in distances, in temperature and the like. The moon, once a corporate part of the earth, has left it through tidal action and will move still farther away for something like fifty millions of years, after which it will return. The sun is a mass of gas, which by its contraction through gravitation has become exceedingly hot, and is radiating its energy away at a definite and known rate. As it is limited in size and amount of material, one may without difficulty calculate that the supply of heat from it will last about ten millions of years. It will cease to shine and become cold unless something like a catastrophe shall reendow it with high temperature and larger volume, when it may repeat the history of these millions of years past. The same conditions of contraction and rise in temperature are observable in

thousands of the heavenly bodies, and in all stages from thin gaseous masses to cold non-luminous solid bodies.

Now that we know so much of the past history of the solar system, and in addition that our nearest neighbor is more than 200,000 times the distance to the sun, also that the whole system is itself moving in space at the rate of about 400 millions of miles a year in the direction of the star Vega, we yet need to know whether this motion is a drift or part of an orbit. At present no one knows. The directions and rates of motion of a number of stars have been very well determined, but such measures are not numerous enough to enable us to say whether there is more order in the movements of stars than there is among the molecules of a gas, where molecular collisions are constantly taking place. Such phenomena as that of the new star which suddenly blazed out in Perseus are now explained only by assuming stellar collisions wherein the masses are so large and have such velocity that impact at once reduces them to incandescent gas. This means the possibility of such disaster to the solar system, but it is a present comfort to know that if we were to collide with our nearest neighbor at present rate, 12 miles a second, it will take nearly 50,000 years to reach it.

We have now about a hundred million stars in sight, and astronomers have been surprised that a greater number of the more remote ones are not to be seen. The actual number of stars in our universe is much smaller than had been supposed, and instead of there being an infinite number in an infinite space the present outlook is that there is a boundary to the visible universe; but this remains to be determined, and this problem is engaging attention in several of the great observatories. We all want to know what kind of a universe we live in and the series of events that take place in it. In older times there were supposed to be but seven members of the solar system. The nineteenth century discovered more than five hundred. Eros was discovered only six or eight years ago, while additional moons to both Jupiter and Saturn were seen for the first time within ten years. It is not probable that all have been discovered. Search is yet being made for other planets.

Though limited, one can get some idea of the magnitude of the universe when it appears that some of the remote stars are so far away as to require something like a million years for their light to reach us, though light travels at the rate of 186,000 miles a second—a distance so great that it would take trillions of years to reach them at the rate that we now are moving in space, namely about 400 millions of miles a year. Space seems illimitable, time is long, and if matter be indestructible, yet the solar system as we know it will have gone through all its phases of growth, maturity, old age and death, long enough before the general aspect of the heavens will have been greatly changed

from what they are to-day. This is astronomical work of importance awaiting research.

We desire to know much more concerning the individual planets. Everybody asks, 'Are the planets inhabited?' and no favorable answer has yet been given. If one means by the question, inhabited by such beings as we are structurally, then one can say that if one of us were transported to any of the planets we could not live there a minute. Some, like Jupiter, are too hot; others, like the moon, too cold, or without air to breathe or water to drink, or with too great or too little gravity for our bodies. One does not need to assume such likeness, especially since we know something of the past history of man and animals on the earth, adapted to it in form, size, structure, habits and intelligence all correlated. To assume intelligence of our type is hardly allowable any more than for structures like ours. Vertebrate skeletons are not necessarily the only form in which intelligence of high type may abide. The implements and skill of the astronomers are yet to determine what can be learned about this question. Taking what we know about the development of life on earth, it would seem to be insanely improbable that among the millions of millions of huge bodies in the universe, all apparently made of the same kinds of matter and subject to the same laws, that the earth is the only one among them all to have life and mind developed upon it. But at present we do not know that it may not be true. Let the twentieth century find out.

Geology: The whole of geology was a gift of the nineteenth century. There was nothing that deserved the name before it, yet more than half of the land of the globe has not yet been surveyed, and many geologic problems are yet unsettled, concerning regions that have been studied. The mineralogical relations and precedents among basalts, granites and other rocks, as well as the physical conditions that determined composition, arrangement and distribution, remain to be determined. Volcanic phenomena are not at all well understood. The composition of the interior of the earth is quite unknown; its temperature, and the rate of heat conductivity of the various rocks —questions which, when answered, will have much to say about the age of the earth and especially of the length of time since it has been a habitable body for any living things. At present there are two camps interested in this question, with lower time limits from ten million to a thousand million years. When Asia, Africa and South America have been as well studied as Europe and North America have been, there will probably be found vast stores of metals, coal, oil and valuable minerals, thus adding to the world's stock of needful things. Also the discovery of new varieties of fossils, the ancestors of living species, especially of mankind, missing links, will add to the interest in human affairs. Geologists have for years been trying to find some

definite measure for geologic epochs, to ascertain how long ago the glacial age was, and how long it lasted. At present there are only surmises that the glacial epoch ended from 10,000 to 50,000 years ago. The twentieth century will probably be able to settle this.

Chemistry too as a science was nineteenth century product. There were guesses and ingenious surmises, but there were no known general laws, such as of definite proportions, of atomic weights, of energy in reactions and the like. It became possible to measure approximately the sizes of molecules and atoms, to know definitely their rates of vibration, and molecular structure is, for many compounds, made out about as well as if they could be dissected and their atoms handled like so many parts of an engine or dynamo.

As knowledge grew on the basis of experiment, generalization of course was attempted, and as physical phenomena were inextricably interwoven with the chemical, constant modifications were required. Not a few propositions found their way into books and general use which had to be abandoned. Thus, it was assumed that when molecules of salt, NaCl, were dissolved in water, each molecule retained its identity and moved as a whole in the liquid. We now know this is not true, but each atom becomes practically independent and moves like a gaseous particle in the air, producing pressure in the same way and for the same reason. The new knowledge has made it needful to revise again some of the notions that were held, and so profound is the change required that some years will be needful to bring chemistry as a science into satisfactory relations with physics. That is not all. We have all been taught and have probably had no misgivings in saying that matter is indestructible. Much philosophy is founded on that proposition. But we are now confronted with the well vouched for phenomenon from two independent workers that under certain conditions a certain mass of matter loses weight, not by mechanical removal of some of its molecules, but by the physical changes which take place in it. This is a piece of news that is almost enough to paralyze a scientifically minded man, for stability of atoms, unchanging quantity and quality, seems to be at the basis of logical thinking on almost all matters. In the 'Arabian Nights' one may expect that the unexpected will happen—genii may be summoned to do this or that, matter may be created or annihilated at will—and the conception gives one pleasure though one knows it to be impossible, and one thinks it impossible because one has never known such changes in matter, and because one has been taught that matter is indestructible. The amount of change is slight in the experiments related, yet well within the possibility of measuring, and one may be sure that from now on the most expert and careful and patient experimenters will attack this question and verify or disprove it. If it be disproved, we shall be philosophically where we have so long been. If it be proved,

it will be the most stunning fact that has come into science for a hundred years. The nebula theory, the doctrine of evolution, and the antiquity of man will be trifles compared with its significance.

Chemistry, though, with or without that fact, has a wonderful field where one may work intelligently in a constructive way. Compounds both inorganic and organic have been produced in great variety, and some chemists are at work trying to make artificially many things which one has to depend upon nature for now—thus quinine, now used in such great quantity; others are sugar or albumen for food, or nitrates for fertilizers, and so on. All these products, if produced on a commercial scale, would be of enormous worth to the world. Aside from these the chemical preparation of antitoxins for the relief and cure of many diseases, cholera, plague, yellow-fever, typhoid fever, are all being sought for with a great probability that they will be discovered and the life of men be saved for many years. I wish I could say that if life be saved and kept by such artificial means that mankind would not seek other ways of decimating its ranks. The average life of the Jews is upwards of seventy years. If all men had the same degree of vitality the world would be so crowded in a hundred or two hundred years that only the loss of fertility would save the necessity for famine, war and pestilence. Chemistry may give us a boon and leave nature to find some other resource for reducing numbers. That such resource would be radically different from her past methods is not very probable.

Physics is that science which is concerned with transformable energy and its transformations under all kinds of conditions. The energy may be mechanical, chemical, thermal, electrical, gravitational, physiological or mental. So long as they are transformable they are all departments of physics. The nineteenth century correlated them all and showed the conditions for transformation and the nature of several forms, thus heat, as vibratory atomic and molecular motion, radiant energy a wave motion in the ether. The discovery of the ether and many of its phenomena belongs also to it. The development of many arts and industries followed the new knowledge, so we have now, for instance, the electrical industries in many ways, the spectroscope and its astronomical revelations, the telescope grown from a four inch objective to a four foot objective.

The old ideas of the nature of matter or of atoms have all been abandoned and we have come to the conclusion that matter is not inert but is loaded with energy, that indeed the ether is saturated with it, though it is available to us only through the agency of matter, which acts as a transformer and a distributor of it. Yet we need to know much more of it. There is more to be learned about chemistry in its relation to physics than any seems to have considered hitherto. It is the form of energy which is present in atoms. Thus when hydrogen

and oxygen unite they give out a surprising amount of energy in the form of heat. A single pound of this combination, taken at ordinary temperature, will give out an amount of heat equal to seven million foot pounds of work, or sufficient to raise a ton one half mile high. We know that heat is a vibratory kind of atomic and molecular motion and the rate of this vibratory motion is the measure of the temperature. The question is as to the antecedent of the heat which thus appears. In what form does energy exist in atoms? Up to this time we have been able to trace energy through its various forms until we come to atoms; there it has eluded us. We say 'chemical energy,' but we have no idea how it differs from heat or from gravitative energy. It is a mystery. What form of motion or stress can be thus embodied? In some way it is related to the ether. It seems as if in some unique manner atoms drew from the ether as from a common reservoir, each particular atom capable of holding so much of that kind and no more, like pint cups and quart cups, and this at once transformed into heat at the instant of combination. When combinations of atoms such as water are decomposed, they again absorb the energy spent to separate them, and an atom therefore possesses more available energy than any combination of atoms. It seems as if atoms acted as transformers of ether energy into the ordinary and familiar forms, such as heat and electricity, and *vice versa,* transforming the latter into ether energy. When we learn this secret we may likely enough be able to artificially extract from the *ether* as much energy as we need for any purpose, for as I have said, it is inexhaustible, and every cubic inch of space has enough for all the needs of a man for many days. This seems fairly probable, and when the source of atomic energy is discovered, it will rank with the greatest scientific achievements of all time. We shall know more of the ether, of the structure of matter, of the antecedents of most of the energy we are familiar with, as this phenomenon underlies most if not all of the phenomena in all the sciences.

It is yet regarded as a mechanical paradox that a medium without friction should have waves set up in it by molecular vibration, and little is known of the physical relations existing between matter and ether by which electrical and magnetic phenomena are produced, and one may say that of the nature of ether we know nothing. Think of the amazing extent of it. As limitless as space itself, with no break or separation of its parts, not made up of particles like matter, but completely filling space and so constituted that any movement of a particle of matter in some way affects the whole body of it to the remotest part of the visible universe.

The nature of gravitation is as unknown as the nature of life itself. We know how it acts, and that this action is millions of times

quicker than light, but that is all, and the one who unravels the mystery will deserve to rank with the greatest of discoverers.

In like degree are we ignorant of electrical and magnetic phenomena which depend upon the ether. When the ether is understood we shall be able to understand in a mechanical sense how moving a magnet disturbs every other magnet wherever it may be, why chemical compounds are possible, why crystals assume geometric forms, and why cellular structure in plants and animals can embody what we call life. To discover the nature and mode of operation of this ether is the work of the twentieth century, and we may be sure that he who accomplishes this will deserve to rank with the highest; indeed it may fairly be said that in importance it is not secondary to anything known, for it is apparently concerned in all phenomena from atoms to masses as big as the sun.

The biologists have great problems on hand for solution. The nineteenth century work made it clear that all the forms of vegetable and animal life of to-day are the product of slow changes in form and functions of living things reaching back millions of years. The successions of some forms were well worked out and the principle established. We call it evolution and everybody nearly believes that this represents the truth in the matter, but how these changes occur and what necessitates them remain as mysterious as ever. Darwin spoke of natural selection. There were all sorts of variations in progeny, and the ones best fitted to the environments survived, but he gave no reason *why* there should be variations, and this is the great question to-day. Many are at work to discover this, and some who have worked in this line have stumbled upon some very unsuspected facts. There has been assumed that like would produce like, and that heredity could and would account for abnormal structures when parents for any reason through new environment had acquired new habits or new structures of any kind. Now it has been shown that such changes of structure or of habit seldom if ever appear in the progeny. For instance, no matter how many generations of mice have their tails cut off each new mouse has the same old length of tail. Each lamb has as many tail vertebræ as did those of hundreds of years ago, though all lambs have their tails cut off when young. Such acquired character is not inherited. Nature pays no attention to any changes save such as she herself initiates, and the conditions she herself adopts remain to be found out. Sometimes she makes monsters and sometimes geniuses, but never by external environment, always *de novo*. This throws overboard the principle good and thoughtful men have so long cherished, that the good habits of one generation would be a hereditary possession of the next. The conditions for heredity are now a most absorbing study among some of the foremost biologists. It is suggestive that at this late day such a reversal of opinion on this ques-

tion has come about and that the question has been run down to cellular structure and molecular arrangement. It will hardly be gainsaid that a knowledge of the proper conditions for changing forms, functions, habits and motives of living beings will be of priceless value to the race, and this work comes to the twentieth century.

Another piece of work, bringing great surprise among biologists as well as the rest of the thinking world, has been given to us within a year or two, namely, that unfertilized eggs have been made to develop in a normal way by subjecting them to certain inorganic chemical substances, such as magnesium chloride. It has been repeated by so many there is no doubt about it now, but its significance is that life itself is a chemical process and does not necessarily depend upon antecedent life any further than such structure contains chemical combinations of proper sort, and that if these be provided in other ways life and growth will result. This research has no more than begun and we may be on the lookout for surprises. A French biologist reports that if an egg be properly cut into as many as sixteen pieces it will develop into sixteen individuals, differing only in size from the normal individual. This opens out a new field, the philosophical importance of which exceeds its biological importance, as can be seen in a minute's thinking. What the outcome will be no one can tell now, but we may envy the biologists who devote their time to such investigations.

A few years ago two German scientific men discovered that a minute drop of a mixture of oil and a salt of potash acted like a microscopic living thing in several ways. It would move about spontaneously, change its form, had a circulation in itself, would gather to itself particles of other matter in its neighborhood, and was sensitive to stimulus from the outside. It comported itself like a thing of life in all ways but one, it could not reproduce its like. The material itself was called artificial protoplasm. The work is still being investigated, both abroad and at home, with the hypothesis that if the proper chemical constituents can be found and added it will then be a real artificial living thing. As it already possesses four of the five distinguishing characteristics of a living thing, ingenuity and persistence will enable some one to find and endow it with the fifth. It will not be safe for one to predict that this can not be done, for it may be done to-morrow, and the twentieth century starts with a pretty problem considered as a physico-chemical problem but the one who solves it, if it should be done, will have reason to be thankful he is not living in any preceding century, for his life would be made a burden to him, if he was not made a martyr.

I have been told by many good people that this question or that question was quite outside of the domain of science and presumptuous in one to inquire into. Astronomy and geology and chemistry are graciously permitted to be in the hands of the man of science, but life

and mind phenomena are declared to be outside the province of physical science, yet the same was said about astronomy and geology and chemistry not many generations ago. Was not Newton condemned for dethroning the Almighty by proposing the law of gravitation for keeping the planets in their orbits? Was not war made upon those who undertook to show that the earth was more than 6,000 years old, and were not the chemists who showed how organic compounds could be formed believed to be enemies of the truth and bent on misleading mankind? Isn't it curious to contemplate that those who know least about a given science should be the ones to set its limits, who know what can not be done or hoped for so much better than those who devote their lives and their best endeavors to discover what is true and what seems probable? To-day men's lives are not endangered as they used to be for their attempts to find an answer to puzzling questions, so the work goes on, and the things discovered are never like what was anticipated by the good and conservative people who know beforehand what can and what can not be known, and it is a bit sad that the latter must die that a new generation may arise to possess the new truth. It took more than two generations to convince the world of the truth of the nebular theory, that the earth was millions of years old, that mankind had occupied the earth for hundreds of thousands of years, and the doctrine of evolution is hardly forty years old, yet are there not many who give it no credence? Perhaps one of the good things which the twentieth century will be able to accomplish will be effectually to warn everybody of the danger of setting any limits to knowledge, also that any opinion mankind has held that has not been through the crucible of science is probably wrong, but the only reason for holding this is that so far every one so tested has been found to be erroneous.

The study of nerves, their connections and activities, has been begun in earnest only within the past few years, but what has been learned seems to lead to as many surprises as has any other branch of science. Only here and there is there now an investigator in this branch, but these have already found out that all nervous action is spent upon the muscles. That all are in one way or another connected with them, that each particular nerve cell has a specific function and substitution seems no more possible among them than can the eye be substituted for hearing or for tasting. At present work is being carried on to determine the functions of various parts of the brain, especially for the effects of use and disuse, the nature of exhaustion, the rate of recuperation, the source of energy and of automatic activity, what happens in sleep, in the hypnotic state, in disease, insanity and in unconsciousness. Dr. Hall has said that the nerves are the most wonderful things in the world, and we know so little about them. Mind and thinking, conditioned by their presence

and activity, on the one hand, and all expressions of them through muscular action as exhibited by motions and emotions.

There are many reasons for expecting most important disclosures from this direction, which may make needful many changes in common beliefs in educational theories and efforts, of responsibility in crime and the proper management of defectives of all sorts. It is not unlikely as great changes as took place during the last century in the beliefs on many important subjects will be required for the work of the twentieth century.

So far I have been speaking of science as related knowledge. Knowledge of such a kind as to react upon our opinions of men, of institutions, society, and the universe as a whole, but science is more popularly conceived as improved ways of doing things, of new products and new possibilities in life, of the arts as managed for economy of effort, enhancing comfort and removing the stress of living. These, however, are not science, but the products of science, and every one is properly concerned to know what changes are likely to come from such a source. The mechanic arts of the last century worked a wonderful change in the modes of living, in the variety and kinds of wants. If we could be deprived suddenly of all save such things as could be had a hundred years ago, we should all be made as miserable as one can think, yet those who lived a hundred years ago were no more miserable than we are. They got as much out of their lives as we do out of ours, and never suffered from thinking they did not have railways, telegraphs, telephones, steamships, automobiles and weather forecasts. These things could never be missed as no one had ever had them, and perhaps most people would have thought a prophet of them to be a romancer.

Many lessons have been drawn from history with the expectation that we may the better order our lives. How many historians there have been, and how few are those whose interpretations have not been wrong! One may recall that squib by Bishop Stubbs, of Oxford, whose contempt for Froude was profound. Canon Kingsley had resigned the chair of history at the university, assigning as reason that what had been understood to be history was unfounded.

While Froude instructs the Scottish youth
That parsons never tell the truth,
The Reverend Canon Kingsley cries
That history is a pack of lies.

These strange results who shall combine?
One plain reflection solves the mystery,
That Froude thinks Kingsley a divine
While Kingsley goes to Froude for history.

One might once fairly have inferred that leisure was what all man-

kind desired. The invention of labor-saving devices, so-called, the cotton gin, the factory loom, the sewing machine *et al.* has turned out sociologically to be very different from that, for the time saved from the old methods has been fully occupied in doing more work, raising more cotton, weaving more cloth, making more clothes. Men have not more leisure because they want something else more than they want leisure. Tastier food and personal adornment are the things that bring the chief stress upon life.

Leisure and idleness are not identical. Leisure is the relief from the stress for maintaining life. There is no leisure for one whose whole time is required to supply food, clothing and shelter for himself and others. When these demands can be met in less than the whole time, the remainder may be called his leisure time and this may be spent in idleness, that is, doing nothing, or it may be spent in doing something else in accordance with one's tastes, aptitudes and opportunities. One may read or study or write or travel, or one may add to one's income by working overtime or at other occupations. Such an one has leisure which he employs in ways that give him a measure of satisfaction. What is called a higher standard of living is almost always the immediate result of leisure—more palatable food, better clothes and houses. If one spends all his income to provide himself with better things than are really needful to keep him healthy, he can not say he has no leisure, for there is no limit to what may be called better things which one may possess and be no healthier or happier. Do not the so-called poor outlive the rich? Whence the centenarians of all countries, Indians, Mexicans, Negroes? Does not nature take as loving care of tramps as she does of the so-called good citizens, who faithfully work and save and build?

To be beyond compulsion to do anything is desirable, of course, for whoever is compelled is so far a slave. During the nineteenth century we were all urged by advice, example and mottoes that thrift was the chief thing. One who did not respond to the pressure was stigmatized as lazy. The hustler was the admired type from pupil to preacher. High speed has been demanded in living as well as on railroads, and he who could not or would not keep up has often had a hard time to live at all. The assumption in all this was that life *should* be strenuous. Our energetic President has publicly urged this. But there are many reasons for holding that it is all wasteful, loading life with miseries and not at all in accordance with Nature's plan. Nature is never in a hurry. She takes ten thousand years to make Niagara Falls and a hundred thousand years to make man, and she spares neither her own work nor man's, as if neither is worth the keeping. In Babylon of old were there not Morgans and Rockefellers, many storied buildings and great armies? Nature has transformed men and armies into gas and shrubbery, the buildings into tumuli, and made a

desert of the gardens. How much better to-day is the world for their energy, their strenuousness and their power? Are we any more lovable or stronger or wiser?

I have sometimes amused myself wondering what question I would ask an inhabitant of Mars, if communication with that planet could be established. If but one question could be answered, what should that question be? Is there any one question which everybody would be willing to have asked and forego every other one? Would it be a question of astronomy or of biology or of philosophy? Each one should settle for himself what that question ought to be, if its answer was to be of interest to all mankind. If it were of a religious or philosophical kind, think what happiness or misery would befall the most of us when the answer came. It would be almost like a judgment day and half the world or more would be thrown into a suicide mood. Ignoring momentous questions, what others are we really most concerned to have answered? Do we not all want to know of the nature of life, of mind, and of all the activities of nature displayed in phenomena? Does not everybody ask, 'What is electricity?' 'What is life?' I do not remember ever to have heard the question 'What is gravitation?' though it is certainly one of the most obscure of all the great activities of nature. Not a particle of matter escapes its hold, and the law of inverse squares we have all learned so glibly, we take on the basis of uniform experience. How can such action be the outcome of inherent properties of matter, and what must be the texture and distribution in the ether so compelling?

Surmises by the score have been made, but none are satisfied with any attempt to find a reason or the antecedents of the phenomenon. It conditions every phenomenon of every kind that comes to our knowledge in a gravitative way, but hitherto it has quite eluded the most ingenious of guessers, and most persons who have been concerned with its problems have either abandoned attempts at its solution or have unwarrantably concluded it is insoluble. There is no good reason why it should be thought of as an ultimate problem, and its solution belongs to the twentieth century or some of its successors. In my judgment its rationale will be found some time.

When, a hundred years ago, men said that heat was caloric, it is plain on a little thinking that such an answer brought us no nearer the real solution. Giving the thing a new name was not an explanation. We have been taught for a generation that heat is a mode of motion, and when we now think of the phenomena we think of brisk changes of position of the minute particles of a body, and that idea reveals heat as a *condition of matter,* not a thing in itself any more than the spin of a top is to be thought of as a thing to be described apart from the top.

A hundred years ago light was thought to be a kind of corpuscle

and now we call it a wave motion in the ether, and say there is no such *thing* as light, it is merely a condition of the ether in the same sense as heat is a condition of matter; and there are some physicists who go farther and declare it to be only an optical illusion, a physiological phenomenon and does not exist apart from the mechanism of the eye. Such have proposed we discard the word light from physical science, seeing it is only a condition of the optical apparatus. At any rate, the nature of light is now so well known and understood that no one thinks of asking the question 'What is light,' but the answer we give is a long remove from the answer expected a hundred years ago.

Here on the threshold of the new century we are confronted with the question 'What is electricity?' and the answer implied by the question seems to demand a something which could be described by one who knew enough, as one would describe some new mineral or gas or thing. Some eminent scientific men are befogged by the question, say it is some ultimate unknowable thing, and hopeless as an inquiry. If it be a something it must be described by its constant properties as other things are. If it be unlike everything else then it can not be described by terms that apply to anything else. All material things have some common properties. A glowing coal is an incandescent solid, a flame is an incandescent gas, but neither glow nor flame exists apart from the matter that exhibits the phenomena. Both are conditions of particular kinds of matter.

If electric phenomena are different from gravitative or thermal or luminous phenomena it does not follow that electricity is miraculous or that it is a substance. We know pretty thoroughly what to expect from it, for it is as quantitatively related to mechanical and thermal and luminous phenomena as they are to each other; so if they are conditions of matter, the presumption would be strongly in favor of electricity being a condition or property of matter, and the question 'What is electricity?' would then be answered in a way by saying so, but such an answer would not be the answer apparently expected to the question. To say it was a property of matter would be not much more intelligible than to say the same of gravitation. At best it would add another property to the list of properties we already credit it with, as elasticity, attraction and so on. In any case the nature of electricity remains to be discovered and stated in terms common to other forms of phenomena, and it is to be hoped that long before this new century shall have been completed, mankind will be able to form as adequate an idea of electricity as it now has of heat.

What thoughtful person has not asked 'What is life?' Many and long answers have been given to this question. One has said 'Electricity is life.' Another 'Life is the continuous adjustment of the internal relations to the external relations.' Which definition tells rather what life does than what it is. Some have imagined it to be

a kind of force, called vital force which presides over the phenomena of living things which may be now in and now out of the matter of the living thing. Vital force as such was mostly discarded as a physiological factor a good many years ago, and in its place was put physical and chemical forces, and to-day most physiologists say that life is reducible to physical and chemical agencies; if it be true, it is not much of an answer to the question 'What is life?' for it leaves us still the question to be intelligibly answered as is the question as to the nature of heat. If one recalls how it has fared with the other queries where more knowledge has given a new and unexpected answer to each, one would be led to anticipate an answer quite different from the one somehow imagined. However it may turn out, there is evidently much work to be done and the twentieth century has the problem plainly before it.

Once more the relation of mind to body waits an answer. Is mind to be thought of as a somewhat, resident in a body, but not necessarily a part of it? If one calls it soul or spirit and thinks of it as separated from body, yet with the same attributes, capable of being now here and now there by an act of volition, unrestrained by physical factors as gravity or heat or the rest, he evidently gets the idea from his philosophy of things in which he assumes limits to the properties of matter before he has exhausted its possibilities and functions. It can not be denied that the physiological psychologists have lately been finding mind all through the bodily structure and giving an entirely different conception of soul from that usually held. However it be in reality, the problem is clearly before the twentieth century workers, and one must rest in agnosticism about it until the knowledge comes.

It seems clear that we have much to learn as to the nature of all the forms of energy, and one appears to be as mysterious as any other, though some of them, like gravitation, are so common and so constant that they awaken no curiosity in most persons and seem to be quite unrelated to personality or to philosophical and religious matters. It seems probable that whoever shall find the meaning of any of these factors will have at hand means for the disentanglement of the whole. With all these problems to be solved is there not enough for the work of the century? and whoever shall catalogue the triumphs of the twentieth century, if he can point to all these or a good part of them will have reason for holding that this century has accomplished as much and as important work as did its predecessor, the nineteenth.

HUMAN AND OTHER FORMS OF CONSCIOUSNESS.

By Dr. HENRY RUTGERS MARSHALL,
NEW YORK.

WHEN we are trying to think clearly we are wont to be disturbed if our friends accuse us of wandering from the sure grounds of science and entering the jungle of metaphysics.

Nevertheless, it must be acknowledged that, without realizing it, all men do really devote a fair proportion of their thought to problems which, strictly speaking, are of a metaphysical nature: and the question as to the relation of 'mind to body,' which has an entrancing interest for so large a body of thoughtful people, is clearly one in reference to which no one can take a definite position without at the same time assuming an attitude in relation to fundamental metaphysical principles.

We turn to the skilled biologist in these days for expert opinion in this matter, only to find him tarred with the same brush; for as a biologist the problem before him has properly no significance. As a biologist he is concerned with forms of 'animal behavior,' to use Lloyd Morgan's happy phrase. If he takes into consideration in any way the consciousness of animals, in that fact he assumes the attitude of the metaphysician. It is clearly because he takes this step into the metaphysical domain, without realizing it, that we find among those psychological biologists who consider the consciousness of animals so wide a divergence of opinion as to the conditions under which such consciousness exists.

But, as I have said, this matter is of great interest to all of us, and is looked upon as deserving our serious consideration. It is quite worth our while then to acknowledge frankly that we are dealing with a metaphysical problem, and at the start to make a rather deep plunge, laying aside for the moment all thought of the consciousness of animals, and asking ourselves what ground we have for our every-day assumption that other men are conscious as we ourselves are.

The ready answer seems to be that they tell us of their conscious states. But evidently this reply does not suffice us, for it becomes very clear upon consideration that no amount of hearsay evidence would serve to convince us of the fact that these other men are conscious did we not note that our activities, which are very like their activities, are accompanied in our experience by modifications in our

conscious life. This very speech of others is a type of activity which we interpret by reference to the modifications of consciousness which go with our own similar speech activities. When, for instance, I say 'yes,' I hear the sound of my own voice and at the same time experience a modification of consciousness which I describe as the state of assent. When my friend says 'yes' I hear the same sounds which a moment ago proceeded from my own body, and I assume that my friend experiences the same conscious state that I describe as assent. In other words, we introject into other men, as it were, conscious states similar to our own conscious states, when they and we ourselves act in the same way, or are subjected to the same stimulations from the environment.

Even when we come to an agreement that consciousness exists in each of us we depend upon this interpretation—this argument by analogy—for our simplest knowledge of the mental states of other men. You and I agree to call the conscious states accompanying stimulations of the eye, light sensations; but in the fact that stimuli of the same nature reach my eye and your eye I have no evidence that what you call light sensations are what I call light sensations, apart from the fact that I judge by analogy that, as you are very like me, you are to be credited when you say that you have a consciousness very like mine; and that as your eye is very like mine, its stimulation by light must correspond with modifications of your consciousness very similar to the modifications in my consciousness that correspond with the stimulation of my eye under the same light conditions.

That this argument by analogy is the basis of our assumption of the existence of consciousness in other men becomes indeed very clear in the fact that we do not hesitate for a moment to pass beyond humankind and ascribe consciousness to the higher animals other than man, although they are entirely incapable of describing their mental states to us.

I have, of course, no fault to find with this manner of our thought; I wish, however, in the very beginning to emphasize this fact, for in what follows I shall attempt to show that in connection with certain generally accepted modern views we are led to follow out this argument by analogy much farther than it is commonly carried, and to results which are of very great interest.

I. *Of Consciousnesses Simpler than Human Consciousness.*

As we have noted, the existence of conscious states in connection with animal activities is naturally inferred by each of us. It is also very generally agreed that the mental life of even the highest of animals is simpler than our own. These conclusions were reached long before men had gained any knowledge of the nature of the human

nervous system or of the fact that all these bodily activities which are accompanied by modifications of his consciousness seem to be dependent upon modifications of the activities of this nervous system.

But coincidently with the advance of knowledge in reference to the structure of the nervous system modern psychologists have quite independently reached the conclusion that human consciousness itself is systemic in its nature. As the nervous system of a given man is looked upon as a closed or definitely bounded physical system; so is his consciousness looked upon as a closed or definitely bounded psychic system.

Furthermore, we have learned that in a general way the consciousness of a given human individual increases in complexity and coordination *pari passu* with the increase of complexity and coordination in his nervous system, in the course of his development from birth to the life of full intelligence.

It is natural for us then to conclude that wherever we find in an animal a closed nervous system of greater or less complexity we have good ground for the assumption of the existence of some form of consciousness of a corresponding greater or less complexity; and this accords, as we have seen, with the every-day assumption of the common man. It is true, as we have said above, that many of our biologists hesitate to accept this commonly accepted view: but it is also true that they fail altogether to furnish to us any valid reasons for rejecting it, being utterly at a loss to give us any satisfactory mark by which to distinguish between animals which are certainly conscious and those which certainly are not.

Modern students of neurology have discovered a further fact of importance to our consideration, viz., the fact that among all animals subject to our study, excepting possibly the very lowest forms in which nervous systems exist, each nervous system is really a more or less complex system of minor nervous systems. The sympathetic nervous system in man, for instance, has a distinct individuality of its own, although it is at the same time a part of the whole broad system: and more or less of such individuality is traceable in connection with many other minor systems within the whole nervous system.

It is interesting then to note that the psychologist also finds himself compelled to look upon human consciousness not only as a psychic system, but as a broad system of minor psychic systems. For instance, our ocular sensations and their resultants are in themselves systematized; and our aural sensations and their resultants are also, although differently, systematized; while at the same time they are both parts of the whole psychic system which we call consciousness. Each group has a measure of individuality, each forms a minor system within the broader conscious system.

Now some of these minor nervous systems in the higher animals display characteristics which enable us to compare them somewhat accurately with the whole fully developed nervous systems of certain of the lower animals which on the basis of our argument by analogy we must, and in fact usually do, agree to have corresponding with them certain lower than human forms of consciousness.

This being true, it surely follows that if any of these minor nervous systems of ours could be separated from the preeminent part of the nervous system—*i. e.*, the brain—and still live, then these separated minor nervous systems within our bodies would have corresponding with them consciousnesses of low grade, which would be separated from what we may call the preeminent or brain consciousness, but which would nevertheless still be consciousnesses, and within the human body.

We are led then to ask whether thoroughly disconnected living minor nervous systems can under any conditions exist within the human body, and to this question we find that we must give an affirmative reply.

Suppose you were shown a frog with its head covered so that it could not be disturbed by your movements, and fastened with tapes to a board, but with both legs free.

Now if I put a drop of weak acid, say on its right knee, it would promptly rub the acid off with the back of the right foot. But suppose I fastened this right foot down with tapes, or disabled it permanently, and then again touched the right knee with acid; the right leg would struggle in the attempt to rub off the acid as it did before; but being unsuccessful because of the binding tapes or injury, after a moment of quiescence or hesitation, it would rub the acid off with the foot on the other side, *i. e.*, the left foot. The common man would be likely to say, offhand, that the frog displayed a good deal of intelligence in this.

But now suppose I remove the head bandage and show you that the frog's head, and with it its brain, had been entirely removed. Experiments show that the frog will act in exactly the way above described if its brain is extirpated.

Now when you discovered this fact, if you made any remark, you might *properly* say: 'What a high degree of intelligence is involved with the mere activities of the spinal cord.' The average biologist, to be sure, usually says not this, but, rather, 'unconscious reflexes simulate the actions due to intelligence'; but I submit that he does this solely because of his preconception that the activities of the cortex of the brain are alone concerned with our conscious states.

The very argument by analogy which leads you to say that other men have consciousnesses because they act thus and so, also leads you

to hold that the live and healthy frog with its brain intact has a consciousness; and if this argument is worth anything at all it must surely lead you also to say that the frog's spinal cord activities have psychic correspondents. And if this is true of the frog why is it not true of man?

In my normal life these psychic correspondents of the spinal cord activities, if they exist, are minor psychic systems within the whole psychic system that I call consciousness. And these minor systems are usually unable to affect attention, although occasionally some of them do so when we are quiescent. We do not note the heart throb now, but we may as we are falling asleep.

We are clearly led thus to see that if disconnection of minor nervous systems from the broad nervous system as a whole can occur, then we may properly assume the existence of minor consciousnesses within the human body.

This view has been suggested long since, but is rejected, and often with derision, by many of our biologists. But in consideration of the facts above referred to it seems difficult to deny its validity, and in the opinion of the writer its rejection is due merely to an unwarranted hesitation to carry our every-day reasoning to its legitimate conclusion. The preeminent nervous system expresses itself by bodily activities of one kind or another, and notably by certain contractions of the throat and respiratory organs, and movements of the lips which produce speech. The sympathetic system, and other practically, or actually, separated minor nervous systems, express themselves by bodily activities of one kind or another exclusive of these activities of speech. While it is perfectly clear that the consciousness which expresses itself in speech, as well as in various other bodily activities, is the preeminent human consciousness, it seems equally clear that there must exist minor consciousnesses which correspond with the activities of minor nervous systems within our own bodies, provided these are, as is the case at times practically, or in some instances actually, disconnected from the main system of nervous systems.

Such disconnection as is necessary for the separate existence of such minor consciousnesses within our bodies may evidently result from pathological lesion, or may be due to the use of the surgeon's knife. But it seems probable that this disconnection may occur in a quite different way, and that if we appreciate this fact we are led to understand the nature of certain phenomena of consciousness which are usually thought to be most mysterious.

In the physical world we note disconnections between systems of activity due to the incommensurability of their rhythm. It is highly probable then that certain active minor nervous systems may become disconnected from others as the result of what we may also call an

incommensurability of rhythm; and we may surmise that the same thing is true of the corresponding psychic minor systems in consciousness which in like manner may be said to be incommensurable.

We have thus a very simple explanation of such facts as the familiar one that the soldier in the wild excitement of battle does not note the painful sensations of the wound in his leg. The brain consciousness is then so intensely active in its relation to the mental states initiated by his sensations of sight and hearing, that these activities are incommensurable with those in the less active minor psychic systems affected by the wound.

But especially does this conception throw light, in cases of so-called 'double personality,' upon the failure of recall by the one personality, of the occurrences in the conscious life of the other personality; and also of the failure of recall by the hypnotic patient, in his normal life, of his mental states during his trance. Here we may assume that two diverse great minor psychic systems, which are utterly incommensurable in rhythm, alternately take possession, as it were, of the body of man, and control his expressions. Being thus incommensurable, the two systems are almost exactly as much disconnected as are two individual men, and of course under such circumstances the mental states of one psychic system can not in any way be revived in the conscious life of the other psychic system.

We may now turn to another important point. We have stepped from the complex fully developed human consciousness to the simpler consciousnesses of the animals. We have further seen that under certain conditions there may be in our own bodies simpler consciousnesses than what we may call, for the sake of brevity, the 'brain consciousness.' But can we not—in fact, ought we not—take a further step, and hold that psychic elements may exist?

Apparently, if we are to be logical, we must take this step. We must assume that if we could isolate a neural element, a psychic element would correspond with its activities. It is true that the neurologist has never been able to discover a disconnected, isolated, living neural element; and it is true also that we can not isolate any psychic element, and even if we could do so, it as an element could not be emphatic *in consciousness* which is necessarily systemic and not elemental.

But now we may note that if disconnected minor neural *systems* may exist in our animal body there seems to be no reason why living neural *elements* may not from time to time become disconnected from, and then again reconnected with, one or another minor nervous system: and correspondingly no reason why psychic elements may not from time to time be disconnected from, and then reconnected with, one

or another minor psychic system within consciousness; some being now cut off, some being now added on, to go to make unanalyzable differences from time to time in what we call our personalities.

If we accept this conclusion, we are led to take one further step which has importance in connection with the consideration of the next division of this article.

We commonly assume that so special a significance is to be given to action within the nervous system in man's organism that it alone can be considered of moment in the relations of correspondence with consciousness. Our modern biologists, however, are coming to see that all protoplasmic substance has powers of interaction—of 'conduction'—similar to those observed in nervous tissue; and that masses of protoplasm may form systems of active life without the existence of anything like nervous systems; nervous matter, indeed, appears to be but a specially differentiated kind of protoplasm which serves as a peculiarly quick and sensitive 'conductor' from part to part of the organism.*

It seems possible therefore to hold that while the form of consciousness with which we are familiar is practically correspondent only with transfers of energy within the vastly complex human nervous system; nevertheless it may be true that any transfer of energy in protoplasmic matter may have a coincident psychic effect; and that consciousnesses of a certain grade may exist in living bodies which are systematized and yet without nervous systems.

If such a view be possible, then we must hold that human consciousness is in all probability complicated by the existence of psychic correspondents of transfers of energy in other protoplasmic masses than those which we designate as the nervous system; although it must of course be granted that the very superior 'conductivity' of the nervous masses makes the part of human consciousness which, under such a view, corresponds with activity of the nervous system vastly more important in the whole of man's consciousness than all the rest of the psychic effects corresponding with transfers of energy in protoplasmic masses other than the nervous tissues.

One more point of a good deal of importance must be noted in this connection.

If we once agree that all transfers of energy in protoplasmic substance have their psychic correspondences, then of course we must

* Confer Loeb, 'Physiology of the Brain,' p. 60 and elsewhere. Professor Loeb scouts the very idea that this, or any other fact, points to the conclusions which we here suggest; but I judge that this is because 'consciousness' for him means something much narrower than it does for us here.

allow that there are consciousnesses of a lowly and sluggish nature in connection with the lowly and sluggish life of the plants. This, it will be remembered, was a point defended on other grounds by the great psychologist Fechner, and which has since been upheld by not a few, among whom we may mention a man of as high position as Paulsen.

But this point we must pass over with this mere mention, for we have problems of greater interest to consider.

The final test of any theory lies in the explanation it gives of the mysterious; and it is a very cogent argument in favor of the broad view of the nature of consciousness thus taken that in connection with these conceptions we have a completely satisfactory answer to the old time puzzle as to the moment of the beginning of the individual soul life.

Perhaps it may be well at this juncture to recall two points made above.

1. That a fully developed human consciousness is a complex system of minor psychic systems—a system of minor, less developed consciousnesses; and that consciousness under the broader conception just reached corresponds with the activities in a fully developed *physical* system which is a system of minor less developed *physical* systems, of which the nervous system is of preeminent importance indeed, but not alone of significance.

2. That if any one of these minor *physical* systems is cut off from the whole *physical* system a minor consciousness may be held to correspond with the activities in this cut off minor system.

In the human species, to which in this connection we may confine our attention, the unfructified germ cell is a living protoplasmic particle which is cast off from the body of the female; and, under such a view as we have above been led to hold, so long as it is a living particle, it has corresponding with its exceedingly lowly activities, an exceedingly lowly form of psychic existence.

While it was part of the body of the female it had its little part in forming the totality of those systemic physical activities to which corresponded the female's consciousness.

If the germ cell happens to be fructified, and attaches itself to the internal tissues of the body of the female, notwithstanding that this attachment is only of such nature that our biologists call it parasitic; nevertheless, under the view here taken the cell again becomes part of the whole bodily system of the mother, and its activities again play their lowly part in the production of the systemic action of the whole body, which has its correspondent in the whole of the consciousness of the adult female.

This germ cell under these conditions, within the female, and in connection with her body, develops very rapidly into the embryo. It is true that the relation of the embryo to the mother continues to be almost parasitic in its nature during its development up to the time of birth, as it also remains for a considerable time after birth. Nevertheless, it draws its nourishment from, and is in a broad sense systemically related to, her body. For as part of her bodily system no activity in any part of the embryo can be without *some* direct or indirect effect upon each and every part of the body of the mother; and no activity in any of these parts of the mother can be *totally* without direct or indirect effect upon it.

The psychic coincidents of the activities in the embryo are thus part and parcel of the mother's consciousness, if this is considered in the broad way presented in the preceding section.

As the embryo grows, within it develops a nervous system of its own, and if our view is correct a minor form of consciousness must exist in connection with the activities of this rudimentary nervous system.

It is true that, so far as we know, the nervous system of the embryo never has a direct connection with the nervous system of the mother: nevertheless as there is a reciprocity of reaction between the physical body of the mother and its embryonic parasite, the relation of the embryonic nervous system to the nervous system of the mother is not very far removed from the relation of the preeminent part of the nervous system of a man to some minor nervous system within his body which is to a marked extent disassociated from the whole neural mass.

Correspondingly then, and within the consciousness of the mother, there develops a new little minor consciousness which, although but lightly integrated with the mass of her consciousness, nevertheless has its part in her consciousness taken as a whole, much as the psychic correspondents of the action of the nerves which govern the secretions of the glands of her body have their part in her consciousness taken as a whole.

It is very much as if the optic ganglia developed fully in themselves, without any closer connection with the rest of the brain than existed at their first appearance. They would form a little complex nervous system almost but not quite apart from the brain system; and it would be difficult to deny them a consciousness of their own; which would indeed form part of the whole consciousness of the individual, but which would be in a measure self-dependent. Should the optic ganglia when fully developed be separated away from the brain; then what was once a minor system within the whole brain system would become a new individual with an optic consciousness all its own.

Now something not unlike this happens at birth. Before birth the minor physical system, *i. e.*, the embryo, though lightly attached to, is nevertheless part of the physical system of the mother: and the psychic correspondents of its activities form part of a complex consciousness which is that of the mother and embryo together; the psychic correspondents of the activities of the mother, as exclusive of those of the embryonic parasite, being of course preeminent in such a complex psychic system.

At birth we have a disruption of the less developed, from the more developed, physical system; and corresponding therewith we have a minor consciousness of low development 'split off' from the more highly developed preeminent consciousness of the mother which remains to all intents and purposes intact. The new 'split off' minor consciousness then begins its existence as an individual entity, and as time goes on develops into a full formed human individual consciousness.

II. *Of Consciousnesses more Complex than Human Consciousness.*

We may now turn to the question whether there are other forms of consciousness still more complex than those forms of human consciousness with which we are familiar in our own life of reflection.

The fact that each human consciousness is a psychic system which is a complex of minor psychic systems, which are themselves highly complex systems of psychic elements, leads us to see that it is by no means impossible that our own complex psychic systems, taken as wholes, *i. e.*, our own consciousnesses, may be joined with other complex psychic systems, *i. e.*, other consciousnesses, in the formation of consciousnesses of still higher grades of complexity.

We are led thus in the first place to consider whether there is any possibility of the formation of such higher systems—of such higher consciousnesses—from the combination of the consciousnesses of human beings aggregated in social masses: whether, in other words, there can be any such thing as a 'social consciousness'; and whether coincidently the aggregates of individuals in social bodies may rightly be looked upon as a 'social organism.'

The first thought which suggests itself to us in this connection seems to argue against such a notion, for we are accustomed to hold that the neural systems with which the consciousnesses of men are correlated are what we call closed systems, and as such are physically disconnected completely from one another; and if such is the case it would seem impossible to imagine the coincident consciousnesses united into a unified system.

Upon second thought, however, we are led to ask wherein consists the bond between the minor neural systems, within the great neural

system, in any individual man; and when we ask this question we find ourselves bound to acknowledge our dense ignorance. It is easy to speak of the 'integration' of these systems; but difficult to explain in what this 'integration' consists. All that we are able to assert is that the minor systems are contiguous, and so connected that together they act as a unit. But evidently this contiguity and connectedness within the neural systems of individual men are of various grades, as the unification of the activity between the several minor systems is of different grades.

We are led to note furthermore that when, for instance, any of us touches the hand of a fellow man, the nerve terminals of his neural system are contiguous with, and active at the same time with, the corresponding nerve terminals of that fellow man; and that his neural system and his neighbor's neural system at such a moment form in a sense one still more complex neural system, in which there are two great minor systems in either of which may occur the inception of changes in grade of activity, but in which this inception of activity must affect both parts of, that is the whole of, what we may call the duplex system. No action in the nervous system of one (A) of the two men (A and B), under such conditions of contact, can be without some effect upon the activity of the nervous system of the other man (B); nor can this action in the one man (A) fail to be influenced by the existing conditions of activity in the nervous system of that other man (B).

Taking one step further we note that the nervous systems of two or more individuals living in the same physical environment may be connected by common stimulations the most important of which are those of ocular, or of aural, nerve terminals—and by those signs and symbols in language, spoken and written, which are substituted for these stimulations—just as well as by the common stimulations of touch nerve terminals of which we have just spoken; and we are thus led to see that after all it is not at all impossible to surmise that the individuals of social groups who are similarly constituted, and who are affected at the same time by the same stimuli from the environment, may be organically interrelated elements of a social body to which must be coincident a social consciousness.

We find then that our consciousnesses may not improbably be minor psychic systems which are parts of a greater social psychic system; that we are warranted in assuming that there may be social consciousnesses of which our individual consciousnesses are elementary parts. But we can not accept such a position without making certain reservations to avoid misunderstanding.*

* For a fuller discussion of this subject confer my 'Instinct and Reason,' p. 189 ff.

In the first place it seems clear that it is improper to speak of the opinions of aggregates of men, as we comprehend them, as a 'social consciousness,' as our extreme sociologists are wont to do. If such a social consciousness exists, our thoughts are elements of it, in very much the same sense that our sensations are elements in our individual consciousnesses. As our individual sensations do not, and as no mere massing of such sensations could, make our consciousnesses what they are; so the mere massing, so to speak, of the thoughts of men can not make a social consciousness. If it exist, it must be something beyond our ken; something that we, as parts of it, can no more expect to grasp than we could expect our sensations to grasp the nature of our consciousness as a whole.

If there be a social consciousness of sufficiently high grade corresponding in general form to our individual consciousness, it may know our thoughts, much as we appreciate the existence of our own sensations and their elementary qualities; and it may have means of expression that are effective for other consciousnesses of its own order; but we as elements of this wider consciousness can surely not be able to grasp even dimly the intimate nature of that higher consciousness which, if it exist, must be determined by the pulse of thought of many interrelated individual consciousnesses. What sociologists are often tempted to speak of as the 'social consciousness' should therefore properly be spoken of merely as the related consciousnesses of the individuals composing social groups.

In all that has preceded this we have given our attention solely to the study of animal and vegetable life, and have left entirely unconsidered the possibility of the existence of anything of a psychic nature in correspondence with inorganic matter.

But, if we allow ourselves to consider such a view as that presented above, we are led further to surmise, as many thinkers have already done, that not merely such transfers of energy as occur in protoplasmic matter may involve correspondent psychic effects, but that all transfers of energy, whether in living or non-living bodies, may involve correspondent psychic effects, even though they be of a nature which we can but little comprehend.

This view which Paulsen* refers back to Plato and Aristotle, and traces in the thought of Spinoza and Leibnitz, Schelling and Schopenhauer and Lotze, and which was so clearly stated by Fechner, is in line with the ever-diminishing distinction between organic and non-organic bodies with which the scientist is making us so familiar. It is a view which has been considered by the large body of conservative thinkers in the past as exceedingly imaginative, and not one to

* 'Einleitung in die Philosophie,' p. 97.

be taken too seriously. In the light of the results of modern investigation, however, it surely appears that this view must be given careful consideration.

One of the distinguishing characteristics of living organisms lies in the fact that they are composed of a unified aggregate of elements, which are so related in a system that no element can be modified without the production of some modification in all the other elements, and in the system as a whole; and so related that the system as a whole can only be modified through the modification of its elements.

Now we have reason to believe that mere physical elements within the universe are so related together that they form systems of various degrees of complexity, and of this very same nature; that is, that elements within the physical universe are bound together in systems of greater or less complexity; in which systems the elements are so related that no one of them can be modified without the production of some measure of modification in all other elements of the system, and in the system as a whole; and so related that the system as a whole can only be modified through the modification in some measure of each of its component elements. It thus appears that systems which by a slight stretch of language we may speak of as *quasi* organic may exist in aggregates of physical elements which are usually spoken of as inanimate and inorganic.

If then an organism can be said to exist in any aggregate of physical elements whenever there exists a reciprocity of reaction between the elements of the aggregate; and if there is a thoroughgoing correspondence between psychic forms and transfers of physical energy, then there must be some type of consciousnesses corresponding with the types of inanimate systems above depicted. These consciousnesses must indeed be of forms very different from human consciousness as we know it; and, in most cases likely to be considered, must be of forms which we would be likely to consider as of a very low degree of 'integration' in comparison with human consciousness.

If now we consider the universe as a whole, as inclusive of all of what we usually speak of as organic, and as inorganic; and if we look upon it in a broad way, we perceive that it as a whole must be looked upon as a vast organic system. In it are various parts which are more or less complex systems within systems; and, broadly speaking, all parts of this vast system are in some measure related by a direct or derivative contiguity, and are subject to reciprocity of reaction, so that no element can react without in some measure affecting the activities of all the other parts of the vast organic system, and so that the reaction of any element is affected necessarily by the reactions of each and every one of the other innumerable parts of the whole vast system of the whole universe.

If the suggestions of previous paragraphs are valid, correspondent with this vast organic universe we are compelled to imagine the existence of a universal consciousness in which each psychic element affects every other, and is affected by every other.

As I have said above, this conception, or conceptions closely allied thereto, have been reached by many thinkers who approach the subject from the most diverse standpoints. Let me quote two passages from lately published works by writers of eminence, in which this is exemplified.

In his 'World and the Individual'* Professor Josiah Royce tells us that

> We have no right whatever to speak of really unconscious nature, but only of uncommunicative nature, or of nature whose mental processes go on at such different time-rates from ours that we can not adjust ourselves to a live appreciation of their inward fluency, although our consciousness does make us aware of their presence. My [Professor Royce's] hypothesis is that, in case of nature in general, as in the case of the particular portions of nature known as our fellowmen, we are dealing with phenomena of a vast conscious process, whose relation to time varies vastly, but whose general characteristics are throughout the same. From this point of view, evolution would be a series of processes suggesting to us various degrees and types of conscious processes. The processes, in case of so-called inorganic matter are very remote, from us; while in the case of the processes which appear to us as the expressive movements of the bodies of our human fellows, they are so near to our own inner processes that we understand what they mean. I suppose then that when you deal with nature you deal with a vast realm of finite consciousness of which your own is at once a part and an example.

And in Dr. Stout's 'Manual of Psychology'† we find the following words:

> If the doctrine of psycho-physical parallelism is true the reason of the connexion between conscious process and correlated nervous process is not to be found in the nervous and consciousness processes themselves. Both must be regarded as belonging to a more comprehensive system of conditions; . . . In particular the individual's consciousness, as we know it, must be regarded as a fragment of a wider whole, by which its origin and its changes are determined. As the brain forms only a fragmentary portion of the total system of material phenomena, so we must assume the stream of individual consciousness to be in like manner part of an immaterial system. We must further assume that this immaterial system in its totality is related to the material world in its totality as the individual consciousness is related to nervous processes taking place in the cortex of the brain.

If the notions presented in the previous sections are warranted, then it appears clear that there must be in this universe an enormous variety of consciousnesses corresponding with the enormous variety of types of systematization in this universe. These consciousnesses must vary in breadth and complexity; and as certain minor systems within the whole vast physical system must be more closely systematized than others, so certain of these consciousnesses must be more closely systematized—more nearly closed systems—more self-contained—more individual—than others. Human consciousnesses would in this view be

* Vol. II., p. 225 ff.

† Ch. III., Sec. 4, p. 51 ff.

special forms of such closely systematized—self-contained—individual —psychic systems.

It appears possible then to conceive that in this universe there are innumerable grades of consciousnesses, other than human consciousnesses. At times human consciousnesses may become inherent parts of such other forms of consciousness: and their existence might affect us by resulting in an alteration of what James might call our 'feel.'

We often seem to appreciate that we are swayed by some far-reaching but ill-defined influence of this nature, the effects of which we experience mainly in a negative way when we break away from it.

Lowell has expressed this experience in some beautiful lines in his 'Under the Willows':

> My soul was lost,
> Gone from me like an ache, and what remained
> Became a part of the universal joy.
> My soul went forth, and, mingling with the tree,
> Danced in the leaves; or, floating in the cloud,
> Saw its white double in the stream below;
> Or else, sublimed to purer ecstasy,
> Dilated in the broad blue over all.
> I was the wind that dappled the lush grass,
> The tide that crept with coolness to its roots,
> The thin-winged swallow skating on the air;
> The life that gladdened *everything* was *mine*.
> . . . . . .
> But suddenly the sound of human voice
> Or footfall, like the drop a chemist pours,
> Doth in opacious cloud precipitate
> The consciousness that seemed but now dissolved
> Into an essence rarer than its own:—
> And I am *narrowed* to myself once more.

If such other forms of consciousness exist in the universe, not only may we at times, as we have just seen, become inherent parts of some of those of higher grade than ours; but it is also possible that at other times such diverse consciousnesses may merely attach themselves to ours, as it were, leaving our own consciousnesses essentially intact; but in such cases the other consciousnesses may serve to produce noticeable modifications in our own consciousnesses, which may point to influences from outside of such human consciousnesses as are familiar to us.

All readers of this article are familiar with the voluminous records of facts made by Hodgson and others in connection with the Society of Psychical Research, and brought into prominence in Frederick Myers's lately published work; facts which are more or less mysterious, and which not a few people think of as corroborative of that most vague of hypotheses, the spiritualistic, or spiritistic, hypothesis as it is now called.

Had these records been made twenty-five years ago they would have been immensely more voluminous, because they would have included accounts of what were then the most convincing pieces of

evidence of this hypothesis, but what are now described as phenomena of multiple personality, automatic writing, etc., which if not thoroughly understood, have surely been shown to bear no such interpretation as that involved with the spiritistic hypothesis.

So it seems probable that in twenty-five years from now many more of these recorded facts above spoken of will appear similarly explicable without resort to this spiritistic hypothesis.

Of such of these facts as then remain unexplained, a very small part may be interpreted as fraudulent, but a very large part indeed as due to perfectly honest but false judgments, or to illusions of forgetfulness, and especially to illusions of memory.

The small remnant of these facts which still remain unexplained on well established psychological principles, if they seem tangible enough to point to anything at all, will surely not point to the existence of disembodied human spirits; but rather to the existence of consciousnesses other than human consciousnesses similar to those of which we have just spoken; consciousnesses, as we have said of forms very different from those known to us in our own experience, but which may occasionally attach themselves to ours in such a way as to produce modifications of our consciousnesses which seem to point to influences from outside of such human forms of consciousness as are familiar to us.

If they are found to point to anything, they will surely not point to the existence of disembodied human consciousnesses as I have just said; nor to the existence of disembodied consciousnesses at all: but rather to the existence of consciousnesses so differently embodied that, in Royce's words above quoted, 'we can not adjust ourselves to a live appreciation of their inward fluency, although our consciousnesses do make us aware of their presence.'

I do not hesitate to agree that such influences very probably do affect us, and as evidence in favor of such a view I shall close by quoting the mature convictions of Professor Wm. James, who will be acknowledged to be one of the most acute of introspectionists the world has known.

Referring to certain early experiments of his he says:*

> One conclusion was forced upon my mind at that time, and my impression of its truth has ever since remained unshaken. It is that our normal waking consciousness, rational consciousness as we call it, is but one special type of consciousness; whilst all about it, parted from it by the filmiest of screens, there lie potential forms of consciousness entirely different. We may go through life without suspecting their existence; but apply the requisite stimulus, and at a touch they are there in all their completeness, definite types of mentality and adaptation. No account of the universe in its totality can be final which leaves these other forms of consciousness quite disregarded.

* 'Varieties of Religious Experience,' p. 388.

THE PREPARATION AND PROPERTIES OF COLLOIDAL MIXTURES.*

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IT was by the well-known investigations of the English physicist, Graham, published in the seventh decade of the last century, that the general attention of scientists was first drawn to the existence of a class of homogeneous mixtures, differing materially in their properties from ordinary solutions, such as those of salt and sugar. Impressed by the fact that the dissolved substance as a rule separates from the one class of solutions in the amorphous and often gelatinous state, and from the other in the form of crystals, he designated the former substances colloids and the latter crystalloids, and their solutions have since been commonly known, respectively, as colloidal and as crystalloidal or ordinary solutions. During the period immediately following Graham's classical researches, the subject of colloidal solutions received comparatively little attention. Within the last fifteen years, however, this field has become a favorite hunting ground of both physical chemists and physiologists in their searches after new truths, and greatly has the store of our knowledge in regard to this important state of aggregation been thereby increased. Yet the difficulty in reaching general conclusions as to the properties of these solutions has proved to be a very great one, owing to the complexity of the phenomena and to the apparent contradictions between many of the results obtained with different colloids and by different investigators. Moreover, the original literature of the subject has become so extensive and so detailed as to be almost overwhelming to one who, with limited time to devote to it, desires to obtain a general survey of this field of work. A brief review of some of the more important principles thus far established may, therefore, be of general interest.

It seems appropriate to begin the consideration of the subject with a definition of the class of substances to which our attention is to be devoted. In accordance with the general use of the term, colloidal mixtures are most simply defined as liquid (or solid) mixtures of two (or more) substances which are not separated from one another by the

* This article is based upon a presidential address delivered by the author at the Philadelphia Meeting of the American Chemical Society, December 29, 1904.

action of gravity, however long continued, nor by filtration through paper, but which are so separated when the liquid is forced through animal membranes, the substance then remaining behind being designated the *colloid*. This distinguishes them, on the one hand, from suspensions of fine visible particles, and, on the other, from ordinary solutions, and it implies that the colloidal particles are intermediate in size between the particles of such suspensions and the molecules which are present in ordinary solutions.

It is obvious, however, that this definition is not based upon a really fundamental distinction either in the properties exhibited by the various mixtures or in the character of their particles. It would, therefore, not be surprising to discover that the so-defined group of colloids include substances having very different properties in other respects than that just considered. And the first result of the researches upon colloids which should be emphasized is that there are in fact at least two kinds of dissolved or suspended substances retained by animal membranes, which differ so radically in their other properties that their inclusion in the same class is sure to lead to serious confusion, unless special pains be taken to discriminate between them. As types of these two classes of colloidal mixtures may be taken an aqueous solution of gelatine and one of colloidal arsenious sulphide. The former possesses a much greater viscosity than that of water; the latter does not appreciably differ from it in this respect. The former gelatinizes upon cooling or upon evaporation, and passes again into solution upon heating or addition of the solvent; the latter does not gelatinize upon cooling, and if gelatinized by other means it does not redissolve upon heating. The former is not coagulated by the addition of salts (unless in excessive amount); the latter immediately gives an abundant precipitate. This difference may be readily shown by adding to a tube containing a one per cent. gelatine solution and to one containing a colloidal suspension of arsenious sulphide a little strong magnesium chloride solution, when no effect will be observed in the first tube; while a voluminous yellow precipitate will result in the second. We have, therefore, to distinguish the viscous, gelatinizing, colloidal mixtures, not coagulated by salts, from the non-viscous, non-gelatinizing, but readily coagulable, mixtures. The former class may be designated *colloidal solutions*, the latter, *colloidal suspensions*. This nomenclature is based upon the belief that a more fundamental distinction between the two classes of mixtures is the possession by the former of the characteristic properties of true solutions—osmotic pressure, diffusibility, and usually a limited solubility of the colloid at some temperature, and the absence of these properties in the members of the latter class and the manifestation by them of many similarities to macroscopic and microscopic suspensions. Even though

this may not be a sharp line of division, it is highly probable that typical members of two classes exhibit these properties of true solutions in such a different degree as to make the differentiation an important one. Unfortunately, however, colloidal mixtures have not yet been satisfactorily enough investigated with respect to these properties to enable a classification to be based exclusively upon them.

Colloidal Solutions.

Let us now consider the characteristics of the two classes as manifested by typical representatives, beginning with the colloidal solutions. These substances are, for the most part, obtained directly from animal or vegetable sources and are purified by dialysis. Among the most important are gelatine, agar-agar, unheated albumen, caramel, starch, dextrine, and many natural gums.

A number of the important properties of these colloidal solutions have already been alluded to, but some of them deserve further consideration. The contrasts and similarities between them and ordinary solutions may first be mentioned. Such colloids possess a much slower rate of diffusion, a much smaller osmotic pressure, and a much slighter influence on the vapor-pressure, freezing-point, and boiling-point of the solvent than do corresponding weights of crystalline substances. So small are these effects that whether they exist at all is a question to which much investigation and discussion have been devoted. The now existing experimental data seem to show, however, that the gelatinizing non-coagulable colloids do possess these properties and influences in an appreciable degree. The results of the osmotic pressure determinations in the cases where it has been measured against a parchment or animal membrane, which would not retain the mineral impurities, are especially significant. Thus by this method it has been found that a 6 per cent. glue solution exerts a pressure of about one third of an atmosphere, and that a 10 per cent. solution of the colloids of blood-serum produces one of 40 mm. of mercury. Further investigations in this direction would be of great value. The results of Graham, too, seem to leave no doubt as to the existence of diffusion; he found, for example, that albumen diffused one seventh as fast, and caramel one fourteenth as fast as cane-sugar. Thus, these colloids exhibit the same properties as ordinary dissolved substances, but in a lesser degree—a fact which is explained in accordance with the modern theory of solutions by the simple assumption that they are true solutions, but that their molecules consist of aggregates of the ultimate chemical molecules and are, therefore, of much greater weight and complexity than those of non-colloidal substances.

This assumption seems, however, of itself alone, scarcely sufficient to account for the abnormal viscosity of these colloids, their power of

gelatinization, and their property of permitting the free passage through them of non-colloidal substances, but preventing entirely that of other colloids of either of the two classes. This last property is the same one that is involved in the permeability of animal membranes for crystalloids and their impermeability for colloids, since such membranes are themselves nothing more than gelatinized colloids. Yet it deserves, on account of its great importance, a somewhat fuller consideration. This difference in behavior towards crystalloids and colloids may be readily illustrated by immersing sticks of gelatine or agar jelly in one experiment in a colored salt solution and in another in a colored colloidal suspension, and allowing them to remain for a day or more. Such comparative experiments may be made in a striking way with a solution of copper sulphate and ammonia and with a colloidal suspension of ferric ferrocyanide or Prussian blue made by mixing equal volumes of dilute solutions of ferric chloride and potassium ferrocyanide. Upon removing the sticks after some hours and cutting them in two, it will be noticed that the ammoniated copper sulphate has permeated the stick uniformly to its center, while the Prussian blue has not entered it at all.

Not only are gelatinized colloids permeable to salts, but, remarkably enough, they offer only a very slight, often scarcely appreciable, hindrance to the passage of these substances through them. Thus, accurate experiments have shown that the rate of diffusion of salts and mineral acids is the same, at any rate within one per cent., in a solid jelly containing 3 to 5 per cent. of agar-agar as it is in one containing only 1 per cent. of agar-agar, and it is, therefore, presumably the same as in water itself, though the accuracy with which this latter conclusion has yet been directly tested is much less. It has also been shown that the electrical conductivity of salts in a gelatine jelly is only a few per cent. different from that in pure water, and that there is no sudden change in its value when the jelly sets. This property is, however, dependent on the rate of motion of the ionized molecules of the salt through the medium between the electrodes, and the slight variation in it caused by the presence of colloids, even in quantity sufficient to produce gelatinization, proves that the flow of such molecules is but little impeded by the colloid.

Returning now for a moment to the other side of the phenomenon —the impermeability of one colloid by another—attention may be called to an apparently related fact of much importance, namely, to the fact that the presence of a gelatinizing colloid in a liquid in fairly small quantity prevents the coagulation of colloidal suspensions by salts, and, therefore, usually prevents the formation of a coagulated precipitate when the solutions of two chemical substances are mixed which, under ordinary conditions, give rise to such a precipitate. Thus when aque-

ous solutions of silver nitrate and sodium chloride are mixed, an abundant curdy precipitate is produced, but, if a little gelatine solution be first added to one of the salt solutions, only an opalescence results, and the silver chloride formed by the metathesis remains indefinitely in the state of a colloidal suspension. Glycerine, sugar and even ether in some cases have a similar influence. This result may arise from the fact that in the presence of the gelatine the particles of silver chloride after attaining a certain size are not capable of diffusing, and hence of coming into contact with one another. It is probable, however, that, at any rate in many cases, the gelatine prevents the coagulation by forming an envelope around the solid particle. Whatever may be the explanation of the phenomenon, it is one of great technical importance, especially in relation to photography; for upon it is based the preparation of the so-called emulsions of silver salts in gelatine, collodion or albumen with which dry plates, films and printing-out paper are coated.

Recent investigations have proved that the gelatinization of these colloidal solutions arises from the separation of a portion of the colloid in the solid state in more or less continuous masses. The resulting jelly, or gel, as it is technically called, has been shown to have an irregular sponge-like structure, the web consisting of a solid mixture of the two substances and the interstices being filled with a liquid solution of them. This has been proved in some cases by direct microscopic observation, and in others by separating the liquid from the solid portion by pressure and by analyzing these portions, which were thus shown to have a very different composition with respect to the proportions of the two constituents. Thus one of the investigators of this subject, Hardy, states that when a solution of 13.5 grams of gelatine in a mixture of 50 c.c. of alcohol and 50 c.c. of water is gradually cooled, it remains homogeneous until a temperature of 17° centigrade is reached. Then it separates into two liquid phases, and is seen to consist of small microscopic droplets suspended in a fluid matrix. As the temperature falls, these droplets cohere to one another and at 12° they have become solid, forming a framework built of little spherical masses. The mixture as a whole has then become a jelly. At 14° the droplets were separated and found to contain 18 per cent. of gelatine while the matrix contained only 5.5 per cent. The important statement is also made that the first appearance of the droplets is attended by a great increase in viscosity, while the subsequent increase is a continuous one. The abnormal viscosity of such colloidal mixtures is, therefore, probably always due to a physical heterogeneity of this kind. The investigations made with other gelatinizing colloids, such as agar, albumen, starch and even silicic acid, have led to a similar conclusion in regard to the structure of the jelly.

Colloidal Suspensions.

Methods of Preparation.—The mixtures of this class have been, for the most part, prepared artificially. The principles of some of the methods which have been employed for this purpose may, therefore, be first described.

Of these principles the most important one is, that when an insoluble substance is produced *in the absence of electrolytes* by a reaction between two chemical compounds, it almost invariably separates in the state of a colloidal suspension. By the term electrolyte is here meant any dissolved substance which is a good conductor of electricity, one, therefore, whose molecules are, according to the ionic theory, largely dissociated into electrically charged atoms or atom groups called ions. Most salts and strong acids or bases are such electrolytes; but water, neutral organic substances like alcohol or sugar, and very weak acids or bases, are not. Electrolytes must not be present in considerable quantity, for the reason that ions coagulate these suspensions. Thus, when a saturated solution of hydrogen sulphide, a slightly ionized substance, is added to one of arsenious oxide, also slightly ionized, no coagulated precipitate of arsenious sulphide results, but only a turbid yellow liquid, which, when poured through filter-paper, leaves nothing behind. It will be noted that in this case the other product of the reaction is water, an un-ionized compound. If this reaction be carried out with a solution of arsenious chloride, instead of with one of the oxide, the ordinary precipitate of arsenious sulphide is obtained; for, in this case, the hydrochloric acid produced by the reaction, being largely dissociated into hydrogen and chlorine ions, coagulates the colloidal suspension. So, also, upon adding hydrochloric acid to the colloidal mixture resulting from the former experiment, a large precipitate is immediately produced. As a second illustration of this method, hydrogen sulphide water may be added to a solution of mercuric cyanide. In this case also a black opaque colloidal suspension of the sulphide results; for the three substances involved in the reaction, hydrogen sulphide, mercuric cyanide, and hydrocyanic acid, are non-electrolytes; but, upon the addition of hydrochloric acid, or, still better, of magnesium chloride, to this solution, the precipitate immediately coagulates. It is not necessary, of course, that electrolytes be entirely excluded, but only that they be not present at any point at such a concentration as will produce coagulation. The method is, therefore, of fairly general applicability. Thus, a colloidal suspension of Prussian blue can be prepared by mixing dilute solutions of nearly equivalent quantities of ferric chloride and potassium ferrocyanide; for the other product of the reaction, potassium chloride, has a coagulating effect only at higher concentrations.

A second method which has until recently been even more com-

monly employed than that just described, consists in the dialysis of a salt solution in which a colloidal base or acid is present, either owing to natural hydrolysis or to the previous addition of an alkali or acid. Thus colloidal silicic acid may be prepared by dialyzing either a solution of sodium silicate alone, or one to which hydrochloric acid has been previously added. A dark red but perfectly clear colloidal suspension of ferric hydroxide is obtained by the dialysis of a ferric chloride solution which has been treated with ammonium carbonate until a permanent precipitate begins to form. This process of dialysis is commonly resorted to also for freeing colloidal solutions or suspensions prepared in other ways from mineral impurities. It is most conveniently carried out in parchment tubes, which are now an article of commerce. As the surface exposed by these is large, the process is a comparatively rapid one. The solution to be dialyzed is placed within such tubes, and these are immersed first in running tap water and afterwards in distilled water which is frequently renewed.

There is one other method of sufficient importance to deserve mention, and this is the process recently described of preparing colloidal suspensions of metals by producing an electric arc under water between electrodes of the metal in question. This is most readily carried out with the non-oxidizable metals, such as gold or platinum. When gold is used, red clouds of colloidal gold are formed near the arc, and in half a minute the whole liquid assumes a red color. The method depends on the fact that the metal is volatilized into the arc or spattered into it in an extremely finely divided form, and is then condensed or absorbed by the water, which, owing to the absence of electrolytes, has little tendency to cause aggregation of the particles.

Besides these colloidal suspensions artificially prepared from mineral substances, others can be obtained by dialysis and other treatments from animal and vegetable sources. Among the most fully investigated of these are heated albumen and gum mastic.

Properties indicating Heterogeneity.—Turning now to the properties of such colloidal suspensions, it seems appropriate first to refer to those which indicate that these mixtures really are suspensions of minute particles and not true solutions. The fact that the components of the mixture are separated by filtration through animal membranes or close-grained porcelain filters is not of itself an evidence of physical heterogeneity; for by copper ferrocyanide membranes, prepared by depositing a precipitate of this substance in an unglazed porcelain cylinder, sugar and even salts can be separated from true solutions. In some cases, the presence of particles in suspension in so-called colloidal mixtures has been proved directly by microscopic observation; thus this is the case with the colloidal mercuric sulphide and with colloidal arsenious sulphide when prepared under certain conditions, but not

under others; the same is true of blue colloidal gold, which can be produced in a variety of ways, for example, by the reduction of gold chloride solution by hydrazine. In most cases, however, the colloidal particles can not be seen even under the best conditions; they are, therefore, smaller than one seventh of a micron (1/7000 mm.), which is about the limit of microscopic visibility. It will be of interest to determine whether they can not be detected in many other cases with the help of the new Zeiss microscope, which, by employing quartz lenses and ultraviolet light (having a much shorter wave-length than ordinary light) and obtaining the image photographically, extends the limit of visible diameters to about one half of its present value. With such an 'ultramicroscope' a German investigator, Raehlmann, has already observed the suspended particles in an albumen solution. By the optical method of Sidentopf and Zsigmondy, in which the colloidal mixture is intensely illuminated by a thin beam of light, and the diffused light reflected from the suspended particles at right angles to the beam is viewed with a powerful microscope, the presence of still smaller particles having a diameter of 1/100 micron has been detected in red-gold suspensions and in other colloidal mixtures.

A strong indication of the heterogeneity of colloidal suspensions is furnished also by the familiar optical phenomenon, which is often called the Tyndall effect, and is observed when a beam of light is passed through any medium containing particles in suspension. The beam becomes visible, as does a sunbeam in dusty air, owing to a diffuse reflection of light from the particles. This can readily be shown to occur with colloidal suspensions of gold and of arsenious sulphide. Moreover, in every case where reflection takes place from non-metallic surfaces the reflected light is polarized, and this is found, in fact, to be true of the rays diffusely reflected from a colloidal suspension by examining them with a rotated Nicol prism. It has been shown, to be sure, that not only colloidal solutions (colloidal mixtures of the first class), but also ordinary solutions of some substances with complex molecules like sugar, exhibit this phenomenon, so that it is not a decisive criterion of a suspension. They do so, however, in an incomparably less degree than do typical colloidal suspensions, so that it at least furnishes evidence that the particles in the latter mixtures are of much larger size than are those in the former.

Whether the well-defined colloidal suspensions possess in appreciable degree what may well be regarded as the best single criterion of a true solution—a measurable osmotic pressure—does not, in spite of its importance, seem to have been the subject of investigation by the direct osmotic method. Nor is there conclusive evidence that they show the closely related phenomenon of diffusion. If the existence of these properties to an extent corresponding at all to the size and number of the particles should be demonstrated, it would, of course, prove

that the distinction between colloidal solutions and suspensions is not one of quality, but only one of degree.

Properties related to the Electrification of the Particles.—A quite distinct class of properties may be next considered, which depend not on the size of the colloidal particles, but apparently upon the presence of electric charges upon them.

The most direct evidence of this electrification is furnished by the migration of the colloidal particles through the liquid under the influence of an applied electromotive force. This effect may be well illustrated with colloidal suspensions of arsenious sulphide and ferric hydroxide contained in two U-tubes. The tops of the U-tubes are covered with goldbeaters' skin and are surrounded by wider tubes containing pure water in which platinum electrodes are placed, so that the products of electrolysis collecting around them may not influence the colloid. These tubes are then connected in parallel with the terminals of a 110-volt circuit in such a way that the current will flow through each of them in the direction from left to right. It is some minutes before any result is observed. Then it is seen that the ferric hydroxide has moved down with a sharp surface of demarkation on the side where the current enters, leaving a clear layer of water above, and that the arsenious sulphide has done the same, but on the opposite side of the tube. In other words, the ferric hydroxide particles are moving with the positive current towards the cathode, the arsenious sulphide with the negative current towards the anode. The former are, therefore, positively, and the latter negatively, charged. These results are typical ones: such movement, or migration, as it is commonly called, is exhibited by all colloidal suspensions, and, it may be added, also by fine microscopic suspensions, like those of quartz, kaolin and lampblack. Other basic hydroxides, like those of aluminum, chromium and thorium, and certain dyestuffs, migrate to the cathode just as does the hydroxide of iron. The suspended particles of almost all other substances, whether colloidal or microscopic, migrate to the anode. This is true, for example, of silicic acid, stannic acid, metallic sulphides, salts like silver iodide and Prussian blue, and metals like gold and platinum. Of special interest with reference to the explanation of the phenomenon is the recently discovered fact that an egg-albumen suspension migrates towards the cathode in an acid liquid and towards the anode in an alkaline one.

In regard to the cause and character of the electrification two assumptions deserve consideration: one is that it is simply an example of contact electricity, the colloid particle assuming a charge of one sign and the surrounding water that of the other. This correlates this phenomenon of migration with that of electrical endosmose; for the motion of suspended kaolin, for example, through water against the

positive current is obviously the converse of the flow of water through a porous clay diaphragm with the current. It does not, however, give an obvious explanation of the facts that the basic colloidal particles become positively charged and the acidic and neutral ones negatively charged, or of the peculiar behavior of albumen. The other assumption accounts for these facts. According to it the phenomenon is a simple case of ionization, the character of which may be best illustrated by specific examples. Thus, each aggregate of ferric hydroxide molecules may dissociate into one or more ordinary hydroxyl ions and a residual, positively charged colloidal particle, and each aggregate of silicic or stannic acid molecules into one or more hydrogen ions and a residual negatively charged colloidal particle. Albumen, which is known to be capable of forming salts with both acids and bases, would, acting as a salt, dissociate into an ordinary positive ion and a colloidal negative one in alkaline solution, and into an ordinary negative ion and a colloidal positive one in acid solution. To explain the behavior of neutral substances like gold or quartz by this hypothesis, it is necessary to supplement it by the assumption that in these cases it is the water or other electrolyte combined with or adsorbed by the colloidal particles which undergoes ionization. It seems not improbable that there may be truth in each of these hypotheses, contact electrification occurring in the case of the coarser suspensions, and ionization in the case of those which approximate more nearly to colloidal solutions. It should be noticed that these hypotheses do not differ as to the charge on the colloidal particle itself, the existence of which is in fact experimentally demonstrated, but only as to the location of the accompanying charge of opposite sign, namely, as to whether it is on the water itself or on ordinary ions dissolved in it. This matter is not essential to our further considerations.

Let us turn now to the extremely important phenomenon of the coagulation of colloidal suspensions. It will be seen that this phenomenon is certainly closely related to the electric charges on the colloidal particles. Indeed, it seems highly probable that they remain in suspension because of their electrification. Thus it has been found that egg-albumen, whose particles are shown by their migration to be positively charged in acid solution and negatively in alkaline solution, immediately coagulates when the solution is made neutral. Attention may also be called to another interesting fact having, apparently, the same significance; namely, to the fact that when two colloidal suspensions, whose particles have an electric charge of the same sign, are mixed, they have no influence upon each other, but when two suspensions, with particles oppositely electrified, are brought together, the two colloids combine with each other, and with proper proportions a complete coagulation results. Thus, upon mixing suspensions of col-

loidal gold and of arsenious sulphide, no coagulation occurs, but when the suspensions of ferric hydroxide and arsenious sulphide, which we have seen from their behavior on migration have opposite electric charges, are poured together, there is immediate coagulation, and in a few minutes the precipitate settles, leaving the liquid clear above.

Crystalloid substances are also to be divided into two classes with respect to their effect in coagulating colloids. Non-electrolytes, whether organic or inorganic, have no tendency to produce coagulation; indeed, we have seen that organic substances, like ether, glycerine or sugar, often increase the stability of the suspension. On the other hand, strong electrolytes, that is, substances which are themselves largely dissociated into electrically charged particles or ions, cause coagulation, when their concentration in the solution becomes sufficiently great. Although complete coagulation does not occur suddenly as the quantity of electrolyte is increased, yet the interval between the concentration at which, in a given time, the turbidity becomes visibly greater and that at which the particles have become large enough to settle out or to be retained by a filter is usually so small that a fairly definite concentration can be specified at which each electrolyte causes a certain, experimentally determinable, degree of coagulation in a definite time. Now recent investigations have demonstrated the remarkable fact that this coagulation-concentration is nearly the same for different ions having the same electric charge (or valence), but that it diminishes enormously with increase of the electric charge of the ion of unlike sign to that of the colloid, while it is not affected by a change in the electric charge on the ion of like sign.

These principles are well illustrated by the results given in the table, which were obtained by Freundlich, on the one hand with the negative colloid, arsenious sulphide, and on the other with the positive colloid, ferric hydroxide, by determining the concentration of various salts which in two hours caused such coagulation as would prevent any of the colloid from passing through a hardened filter.

Coagulation-concentration in milli-equivalents per liter					
of As_2S_3, a negative colloid, by			of FeO_3H_3, a positive colloid, by		
NaCl..... 71	$MgCl_2$ 2.0	$AlCl_3$..... 0.39	NaCl 9.3	K_2SO_4 ..... 0.41	
KNO_3... 70	$Ba(NO_3)_2$ 1.9	$Al(NO_3)_3$... 0.41	KNO_3..... 11.9	$K_2Cr_2O_7$..... 0.39	
.....	.....	.....	.....	.....	
K_2SO_4....91	$MgSO_4$.....2.3	$Ce_2(SO_4)_3$....0.40	$BaCl_2$ 9.6	$MgSO_4$ 0.43	

It will be seen by comparing the first two values in each column that so long as the electric charge or valence of the ions of the salt remains the same, their chemical nature has no influence. It will be further seen from the third value in each column that a variation of the electric charge of the negative ion has no great influence upon the

coagulation of the negative colloid, and that this is true of that of the positive ion in the case of the positive colloid. On the other hand, by comparing the numbers in the same row, it will be seen that the coagulation of the negative colloid takes place at a much lower concentration when the salt produces positive ions with a higher electric charge, and that an increase of the electric charge upon the negative ion has a similar effect upon the coagulation of the positive colloid.

It is evident from these facts that it is the ion with a charge opposite to that of the colloid particles that is mainly responsible for their coagulation, but what the mechanism of this coagulation is, is not yet understood, though it has been the subject of much discussion. Interesting though they are, it is not worth while to describe the explanations that have been suggested; for, in the opinion of the writer, mere speculative hypotheses, that is, hypotheses which have not been shown to facilitate to an important extent a knowledge of the actual phenomena, are of little value except to the investigators of them, and to them only because of the possibility of their future development into really useful conceptions. The recent literature of colloids furnishes a striking example of the unfortunate tendency even of our modern investigators and text-book writers to attach greater importance to hypothetical interpretations of imperfectly known phenomena than to a determination and presentation of the laws in regard to them.

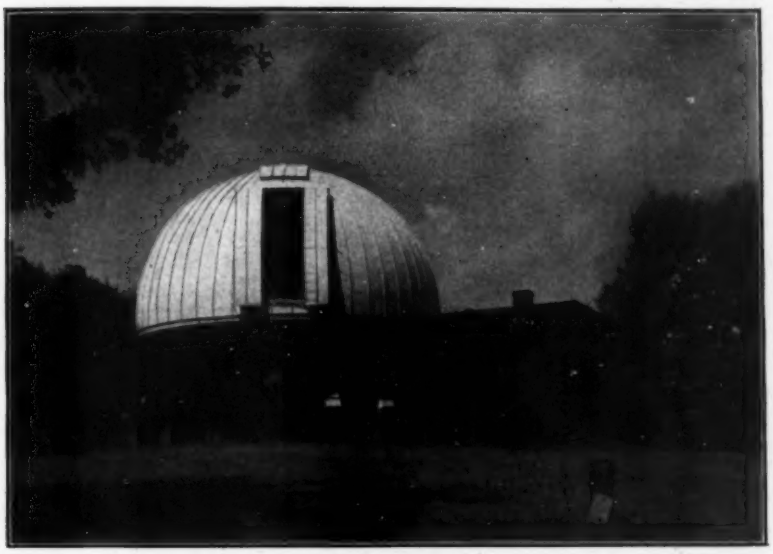
Even an elementary consideration of the properties of colloids should include a discussion of the absorption or coprecipitation of other substances with them when they are gelatinized or coagulated—a phenomenon which is of great importance in analytical chemistry, as well as in other directions. But, for lack of space, this side of the subject will have to be entirely omitted. Moreover, only a mere reference can be made to the importance of a knowledge of the properties of colloids, not only in the industrial applications of chemistry, but also in many other sciences and arts. It must suffice to mention that the industries of dyeing, of tanning, of glass-making and coloring, and of the manufacture of photographic materials and of modern explosives have to deal primarily with substances in this peculiar state of aggregation; that the clarification of syrups and other liquors by charcoal, and that of water and sewage by precipitation, are based on the phenomena of absorption by colloidal substances; that it is with these substances as constituents of living bodies that physiology is mainly concerned; that they constitute the culture-media of the bacteriologist, to the employment of which the development of his science is largely due; and that to the geologist the phenomenon of the sedimentation of mud and slimes, which is closely related to that of the coagulation of colloidal suspensions, is one of much interest.

THE LIBRARY, UNIVERSITY OF VIRGINIA.

THE PROGRESS OF SCIENCE.

THE UNIVERSITY OF VIRGINIA.

THE inauguration of Dr. E. A. Alderman as the first president of the University of Virginia closes a historical period of eighty years, during which the institution has occupied a somewhat unique position in our educational system. The inscription prepared by Jefferson and inscribed on his tomb reads: 'Here was buried Thomas Jefferson, author of the Declaration of Independence, of the Statute of Virginia for Religious Freedom, and Father of the University of Virginia.' The catalogue of the university devotes a page to the statement: "Founded by Thomas Jefferson.—'An institution is the lengthened shadow of one man.'" And it is true that the university has maintained much of the intellectual aristocracy and democratic simplicity of its founder. There was no president, the administration being conducted by the faculty with their elected chairman and a rector and visitors representing the people through the governor's appointment. There were originally eight independent schools or departments—ancient languages, modern languages, mathematics, natural philosophy, moral philosophy, chemistry, medicine and law. A student could matriculate in any one of these schools, and the elective group system was thus early established. There were no entrance examinations; no distinction was made between cultural and professional studies; no degree other than 'graduate' was given on the completion of a course, but those who carried on research might receive the doctor's degree; no honorary degrees have ever been awarded; there were no required religious exer-



THE LEANDER MCCORMICK OBSERVATORY.

cises. The university was one of the first to be endowed and supported by a state, and Jefferson planned that it should be the head of the public school system. Much of this sounds very modern, or rather perhaps in accord with the views of certain modern educators.

THOMAS JEFFERSON, FOUNDER OF THE UNIVERSITY OF VIRGINIA.

Virginia long maintained its position as the university of the south, being its home of scholarship and school of training for public life. Perhaps no other institution in the country prepared so many men for high official positions; and when the civil war came, it supplied about 1,500 officers to the confederate army. In spite of the ravages of the war, it by no means lost its prestige. Thus there are at present seven alumni who are United States senators and at least ten who are presidents of colleges and universities. The illustrations here given show that even after the disastrous fire of ten years ago, the university possesses suitable and beautiful buildings, and that the sciences are well cared for. It will suffice to name Professor Ormond Stone, director of the observatory, and Professor J. W. Mallet, F.R.S., who holds the chair of chemistry, to indicate the position held by the university in the sciences.

Dr. Alderman, who has been superintendent of schools, professor of pedagogy and for four years president of North Carolina and of Tulane, has the educational experience which will become more and more essential for a

college president, and the gift of oratory which perhaps in the future will be regarded less highly than at present. His administration began with the announcement of gifts from our two promoter, certainly makes for organization and bigness, and for at least temporary efficiency. It was, however, a strange irony that led to the celebration of Jefferson's birthday by the

DR. EDWIN A. ALDERMAN, FIRST PRESIDENT OF THE UNIVERSITY OF VIRGINIA.

ubiquitous eleemosynaryists, and there is every reason to foresee that the university will increase in wealth and in numbers. The college president, like the political boss and the corporation inauguration of a president of the University of Virginia. A Jeffersonian democrat may hold almost any political opinions, but presumably the line must be drawn at the benevolent despot.

THE ROUSS PHYSICAL LABORATORY. The Mechanical Laboratory is on the opposite side of the lawn and is identical in appearance with the Rouss Laboratory.

While the accumulation of wealth and a certain kind of efficiency are undoubtedly attained by present methods in politics, in business and in education, they are probably passing phases in our democracy. It would be a severe arraignment of democracy and of higher education to hold that those who make a university can not conduct it. If the people will not directly support a university, they will not continue to do so indirectly through the

THE CHEMICAL LABORATORY.

gifts of millionaires. But the people are ready to maintain their universities. Wisconsin has this year appropriated $725,000 for its university; Virginia would in the end do more for its university than will ever be done by distant millionaires. It seems a pity that some of the complications inevitable in an imperfect democracy and the temporary backwardness of the south in appreciation of educational matters as compared with the central and western states have led the University of Virginia to diverge in the direction of our private eastern institutions instead of maintaining intact the democratic ideals of its founder.

PROFESSOR CHARLES A. YOUNG.

THE retirement of Professor Charles Augustus Young from the active duties of the chair of astronomy and of the directorship of the Halstead Observatory at Princeton deserves more than a passing comment as a news item in this journal. A service of science for a period of more than fifty years in itself commands respectful attention; and the manner in which this service has been rendered, with lofty regard for truth and genuine interest in its diffusion, is almost unique in this generation.

He was to the manor born, for his grandfather, Ebenezer Adams, was professor of mathematics and natural philosophy at Dartmouth from 1810 to 1833. His father, Ira Young, succeeded Ebenezer in the chair and occupied it with distinction until his death in 1858. Charles Augustus, born at Hanover, on December 15, 1834, was graduated as bachelor of arts from the college of his fathers in 1853. He made his first visit to Europe in that year, accompanying his father, who went to purchase instruments for the Shattuck Observatory then in process of erection at Hanover. The notebooks of the observatory contain many of the son's observations recorded during his undergraduate days. After two years spent in teaching the classics at Phillips' Andover, with simultaneous studies in the theological seminary, Charles Young went in 1857 to Hudson, to become professor of mathematics and natural philosophy at the Western Reserve College. During several summers he served as astronomical assistant on the government's lake survey. During 1862 he left his books at the call of patriotism, and assumed for some months the captaincy of a regiment of Ohio volunteers, largely composed of students.

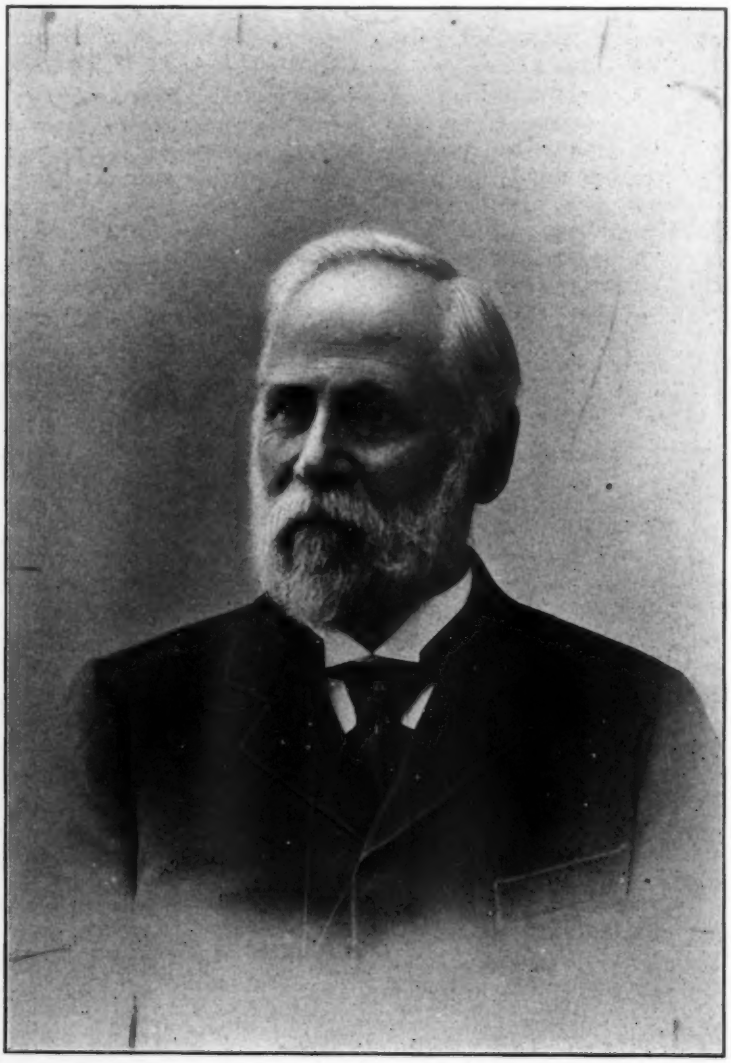
He returned to Dartmouth in 1866, to the professorship of natural philosophy and astronomy formerly held by his father. It is fortunate that laboratory instruction was not then included in the teaching of natural philosophy, for otherwise time could hardly have been secured for the researches in astrophysics to which Professor Young's attention was enthusiastically given in the hours not spent in the class room. The significance of the spectroscope was clearly foreseen by him, and he devoted much time to its development.

At the total solar eclipse of 1869, he observed the spectrum of the corona. He looked for, but did not see, the reversal of the dark Fraunhofer lines at the instant of internal tangency of moon and sun. But in the following year, at a station in Spain, his expectations were realized in his detection of the 'flash spectrum.' This difficult visual observation was not photographically confirmed until the eclipse of 1896, when Mr. W. Shackleton, of Sir Norman Lockyer's party, obtained a fairly good plate; and in 1898 Sir Norman and others obtained very fine photographs of the elusive phenomenon.

In the early seventies, Professor Young assiduously observed the solar prominences and the spectrum of the chromosphere. He obtained in 1870 the first photographic record of a solar prominence, but the lack of sensitiveness of the wet-plates then in use made

it undesirable to follow the matter further at that time.

Professor Young's expedition to Wyoming in the summer of 1872, to utilize the advantages of an altitude of over eight thousand feet, added a hundred chromospheric lines to the list of 170 which he had observed at Dartmouth. It may be mentioned that this list has been but slightly enlarged since that date, and that by Professor Young himself at Princeton. In 1876, with the first grating spectroscope used in astronomical work, he made the pioneer measurements of the rotation of the sun from the relative displacements of lines on the approaching and receding limbs. We are indebted to him for important observations on the spectrum of sun-spots, made after his



PROFESSOR CHARLES A. YOUNG.

removal to Princeton in 1879; also for measurements of Uranus and double stars with the 23-inch refractor of the Halstead Observatory. Professor Young observed the transit of Venus of 1874 at Pekin, that of 1882 at Princeton; and he traveled to favorable points of observation of the solar eclipses of 1869, 1870, 1878, 1887 and 1900.

Despite the value of his original researches, so imperfectly sketched above, it is not for them that we most highly honor Professor Young. Nor is it for the excellence of his numerous textbooks on astronomy, which have been used by far more than a hundred thousand students and readers. It is rather for himself, his own personality, and for the lofty ideals which his life has so fully illustrated. A personal acquaintance is not necessary for the recognition of these qualities, for they appear in all his writings, whether popular or technical. Whatever things are taught must be 'correct and accurate *as far as they go.*' Truth must not be debased for the sake of popularization. The assumption premised must always be clearly indicated; and the limitations of our mode of observation kept in mind. Such principles as these have ever been illustrated by this teacher in his writings, on the lecture platform, and in the classroom.

The total absence of dogmatism or assertiveness. even in works on which he is preeminently an authority (as in *The Sun*), is conspicuous; and his tolerance for views different from his own, with his uniform avoidance of anything controversial in his teachings and writings, furnish an example which many younger and older men could follow to great advantage.

The vein of quaint humor which pervades his speech and literary work have been always appreciated by his friends and readers, and is an obvious part of his genial philosophy of life. Worries, cares and disappointments have not been absent, and for some years ill-health has added its burden. But the gentle influence of an ideal conjugal companionship, extending over more than forty years, always lightened these cares until the crushing bereavement came four years ago.

As Professor Young now retires from active duties upon 'coming of age,' thousands of pupils, readers and friends, salute him. May many coming years be allotted to him, now in the ripe maturity of his mind, for reflection, study and contributions to the world's knowledge of other worlds.

SCIENTIFIC ITEMS.

THE faculty of Princeton University gave a dinner on the evening of May 17 in honor of Professor Charles A. Young, who becomes professor emeritus after a service of twenty-eight years as professor of astronomy. Among the speakers were President Woodrow Wilson, of Princeton; President Francis L. Patton, of Princeton Theological Seminary; Mr. M. Taylor Pyne, of New York; Professor Silas Brackett, Professor W. F. Magie and Dr. Henry Van Dyke, who read a poem. A loving cup was presented to Professor Young.—Professor J. J. Thomson, F.R.S., of Cambridge University, has been elected professor of natural philosophy in the Royal Institution to succeed Lord Rayleigh, who becomes honorary professor.

PROFESSOR GEORGE T. LADD, who has resigned from the chair of philosophy at Yale University, has arranged to pass the latter half of next year as professor of philosophy at Western Reserve University. At the close of the war in the east he expects to go to Japan to lecture on educational methods under the auspices of the Japanese Imperial Education Society.—Sir Patrick Manson has been invited to give the Lane lectures at the Cooper Medical College, California, this year. He will lecture on some aspect of tropical diseases.—The courses that Professor Wilhelm Ostwald, of the University of

Leipzig, will offer at Harvard University during the first half of the approaching academic year are: 'The Philosophy of Natural Science,' three lectures a week, and 'The Fundamental Conceptions of Chemistry' and 'Catalysis,' each one hour a week.

At the annual anniversary meeting of the Royal Geographical Society, on May 22, Sir Clements Markham resigned the presidency of the society which he has held during the past twelve years. Sir George Goldie, founder of Nigeria, was elected to the presidency, Sir Clements Markham and Colonel D. A. Johnston were elected vice-presidents.—Columbia University has conferred its doctorate of science on President R. S. Woodward, of the Carnegie Institution.—Cambridge University has conferred the honorary degree of Sc.D. upon Commander R. F. Scott and Sir Francis E. Younghusband, K.C.I.E., LL.D.

The proposed affiliation of the Massachusetts Institute of Technology with Harvard University was approved at a meeting of the corporation of the institute, on June 9. Thirty-two of the forty-seven members of the corporation were present, and by a vote of 20 to 12 it was agreed to accept the terms of the agreement recently drawn up by the committee of the two institutions. It will be remembered that on May 5 the faculty of the institute adopted by a vote of 56 to 7 the report of the committee adverse to the affiliation.—At the annual meeting of the National Academy of Design it was voted to accept the offer of Columbia University to form an affiliation. It is planned to collect $500,000 for a building, which will be erected on a site furnished by Columbia University.—The cornerstone of the library building of Leland Stanford Junior University was laid on May 15. The building will cost $800,000. At the ceremonies an address to the students by Mrs. Stanford was read. In it she makes the amount realized from the sale of her jewels, which are estimated to be worth $500,000, an endowment fund for the library.

It is proposed to affix a marble tablet to the Villa Medici, which is French property, to remind passers by and posterity that Galileo was kept prisoner there from June 24 to July 6, 1633. Italy has already erected a small monument to Galileo at the very door of the villa, with the following inscription: "The neighboring palace, which belonged to the Medici, was the prison of Galileo Galilei, guilty of having seen the earth revolving round the sun."